International Society of Electrophysiology and Kinesiology

XXI ISEK CONGRESS

JULY 5-8, 2016
CHICAGO, ILLINOIS

HYATT REGENCY CHICAGO

www.isek.org

Bridges to innovation

PROGRAM AT A GLANCE

Time: 800, 815, 830, 845, 900, 915, 930, 945, 1000, 1015, 1030, 1045, 1100, 1115, 1130, 1145, 1200, 1215, 1230, 1245, 100, 115, 130, 145, 200, 215, 230, 245, 300, 315, 330, 345, 400, 415, 430, 445, 500, 515, 530, 545, 600, 615, 630, 645, 700, 715, 730, 745, 800

Tuesday — 05-Jul

- Registration & Conference Information Desk Open
- WS 1A 8:00-9:30am Recency A
- WS 3 8-9:30am Regency C
- WS 4 8:00-9:30am Regency D
- WS 5 8:00-9:30am Toronto
- Break 9:30-10:00am Regency Foyer
- WS 1A 10:00am-12:00pm Regency A
- WS 2 10:30am-12:00pm Regency B
- WS 3 10:00am-12:00pm Regency C
- WS 4 10:00am-12:00pm Regency D
- WS 5 10:00am-12:00pm Toronto
- Workshop Lunch 12:00-1:00pm Regency Foyer
- WS 1B 1:00-3:00pm Regency A
- WS 2 1:00-3:00pm Regency B
- WS 3 1:00-2:30pm Regency C
- WS 4 1:00-3:00pm Regency D
- WS 5 1:00-3:00pm Toronto
- Free Time
- Delsys WS Regency A
- Opening Reception 6:00-8:00pm Rehabilitation Institute of Chicago

Wednesday — 06-Jul

- Registration & Conference Information Desk Open
- Exhibits Open, Posters on Display
- Opening Address & Keynote 1 John Rogers 8:00-9:30am Regency Ballroom
- Break 9:30-10:00am Crystal Ballroom
- Parallel Session: S.1 Regency Ballroom A
- Parallel Session: S.2 Regency Ballroom B
- Parallel Session: O.1 Regency Ballroom C
- Parallel Session: O.2 Regency Ballroom D
- Parallel Session: O.3 Regency Ballroom A
- Parallel Session: O.4 Regency Ballroom B
- Parallel Session: O.5 Regency Ballroom C
- Parallel Session: O.6 Regency Ballroom D
- Lunch / Posters 1:00-2:00pm Crystal Ballroom
- Keynote 2 Birgit Juul-Kristensen 2:00-3:00pm Regency Ballroom
- Break 3:00 - 3:30 Crystal Ballroom
- Parallel Session: S.3 Regency Ballroom A
- Parallel Session: S.4 Regency Ballroom B
- Parallel Session: S.5 Regency Ballroom C
- Parallel Session: S.6 Regency Ballroom D
- Poster Session I 5:00-6:30pm Crystal Ballroom *Sponsored by Northwestern University*
- Free Time

Thursday — 07-Jul

- Registration & Conference Information Desk Open
- Exhibits Open, Posters on Display
- Keynote 3 Irene Davis 8:00-9:00am Regency Ballroom
- Break 9:00-9:30am Crystal Ballroom
- Parallel Session: S.7 Regency Ballroom A
- Parallel Session: S.8 Regency Ballroom B
- Parallel Session: O.7 Regency Ballroom C
- Parallel Session: O.8 Regency Ballroom D
- Parallel Session: O.9 Regency Ballroom A
- Parallel Session: O.10 Regency Ballroom B
- Parallel Session: O.11 Regency Ballroom C
- Parallel Session: O.12 Regency Ballroom D
- Lunch / Posters 12:30-1:30pm Crystal Ballroom
- Keynote 4 W. Zev Rymer 1:30-2:30pm Regency Ballroom
- Break 2:30 - 3:00pm Crystal Ballroom
- Parallel Session: S.9 Regency Ballroom A
- Parallel Session: S.10 Regency Ballroom B
- Parallel Session: S.11 Regency Ballroom C
- Parallel Session: S.12 Regency Ballroom D
- Poster Session II 4:30-6:00pm Crystal Ballroom *Sponsored by Noraxon*
- Free Time
- Congress Banquet 7:30-11:00pm Mid America Club

Friday — 08-Jul

- Registration & Conference Information Desk Open
- Exhibits Open, Posters on Display
- Parallel Session: S.13 Regency Ballroom A
- Parallel Session: S.14 Regency Ballroom B
- Parallel Session: O.13 Regency Ballroom C
- Parallel Session: O.14 Regency Ballroom D
- Break 9:30-10:00am Crystal Ballroom
- Keynote 5 Doug Weber 10:00-11:00am Regency Ballroom
- General Assembly 11:00-12:00pm Regency Ballroom
- Poster Session III with Lunch 12:00am-1:30pm Crystal Ballroom
- Parallel session: S.15 Regency Ballroom A
- Parallel session: S.16 Regency Ballroom B
- Parallel Session: S.17 Regency Ballroom C
- Parallel Session: S.18 Regency Ballroom D
- Break 3:00 - 3:30pm Regency Foyer
- Closing Keynote **Sponsored by ISB** Scott Delp 3:30-4:30pm Regency Ballroom
- Awards 4:30 - 5:00pm
- Closing Reception ***Sponsored by ISB*** Regency Foyer
- Free Time / Travel from Chicago

TABLE OF CONTENTS

About ISEK

The International Society of Electrophysiology and Kinesiology (ISEK) is a multidisciplinary organization composed of members from all over the world in health-related fields, and basic science with a common desire to study human movement and the neuromuscular system.

The purpose of the Society is to promote research and teaching in the disciplines of Electrophysiology and Kinesiology in normal, experimental and pathological conditions of the sensory and motor systems, with emphasis on the interactive use of the two disciplines.

ISEK History

During the International Congress of Anatomy in the Rhein-Maine-Halle, Wiesbaden, Germany in the summer of 1965, several anatomists gathered for a luncheon to discuss the organization of a small society in electrophysiological kinesiology. This group agreed to found ISEK, the International Society of Electrophysiological Kinesiology. Since this meeting, ISEK has been providing a forum for professionals from health-related fields and basic science to discuss research and teaching in the disciplines of Electrophysiology and Kinesiology in normal, experimental and pathological conditions of the sensory and motor systems, with emphasis on the interactive use of the two disciplines.

LETTER FROM THE 2016 CONGRESS CHAIR

Dear Friends and Colleagues,

I am honored to welcome you to Chicago for the 21st ISEK Congress. Chicago is a vibrant city on a beautiful lake. It has a rich culture that includes music, theater, architecture, gastronomy, and sports. I hope it will provide you with many enjoyable opportunities in addition to the science that will be central to our meeting.

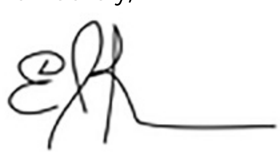
Our local scientific program committee selected Bridges to Innovation as the theme for this year's Congress. This was chosen to reflect our desire to construct a program that emphasizes how ISEK's core disciplines of electrophysiology and kinesiology are having an impact on related areas such as rehabilitation, biomechanics, and ergonomics. Our theme is also meant to highlight how recent advances in science and engineering can drive innovation in our field. We consider these bridges as opportunities for impact and innovation. They are represented in many aspects of our program, including the pre-conference workshops and the list of exceptional keynote speakers. I hope that these unique elements of the 21st Congress challenge you to think about our field in new and productive ways.

We had a tremendous response to the call for symposia proposals that was issued last fall, and many of those proposals have become part of our program. A few related proposals were combined to create some of our pre-conference workshops. Eighteen additional proposals are present as parallel sessions within the main conference. These are indicated as S.1, S.2, S.3 … in the detailed program that follows. The remainder of the program was constructed from the great number of excellent individual submissions we obtained. These are present in the oral and poster sessions of the meeting.

Many individuals and institutions contributed to make this meeting possible. I would especially like to thank the local scientific committee, who have worked for the past two years to plan and implement the scientific elements of the meeting. I would also like to thank all members of our external scientific advisory board for their contributions to the symposia, and help during the review process. The members of the ISEK board have also provided much support and encouragement during this entire process. Finally, I would like to thank our sponsors, who contributed generously to this meeting, and the entire staff at Podium Conference Specialists, who have been instrumental in helping us develop and host this ISEK Congress.

I hope that you have a productive meeting, and enjoy your time in Chicago.

Sincerely,



Eric J. Perreault
Congress Chair

GENERAL INFORMATION

ISEK Leadership

The Society is administered by a Council consisting of a President, Vice-President, Secretary, Treasurer, and five other members, all of whom are elected for a two year term. The Society's Bylaws govern how the Board manages the Society.

THE ISEK COUNCIL CONSIST OF THE FOLLOWING POSITIONS
(ELECTED FOR 2 YEARS)

ISEK President	**Paul Hodges,** University of Queensland, Australia
ISEK Vice President	**Deborah Falla,** University of Birmingham, UK
ISEK Past President	**Dario Farina,** University of Göttingen, Germany
ISEK Secretary	**Kevin McGill,** Stanford University, USA
ISEK Treasurer	**Karen Sogaard,** University of Southern Denmark, Denmark
Council Member	**Edward (Ted) Clancy,** Worcester Polytechnic Institute, USA
Council Member	**Francesco Felici,** Università degli Studi di Roma Foro Italico, Italy
Council Member	**Claudio Orizio,** Università degli Studi di Brescia, Italy
Council Member	**Daniel W. Stashuk,** University of Waterloo, Canada

2016 SCIENTIFIC PROGRAM COMMITTEE

Program Chair	**Eric Perreault,** Northwestern University
Scientific Program Chair	**Matt Tresch,** Northwestern University
Local Arrangements Chair	**Levi Hargrove,** Rehabilitation Institute of Chicago
Fundraising Chair	**Yasin Dhaher,** Northwestern University
Scientific Review Chair	**Elliott Rouse,** Rehabilitation Institute of Chicago
Chair for Workshops & Symposia	**Wendy Murray,** Northwestern University

Membership Information

ISEK membership is open to all scientists, principal investigators and students from around the world, pursuing research whose goal is to understand human movement and the neuromuscular system. The ISEK membership term runs for 2 years from October 1 through September 30; the current term runs from October 1, 2015 to September 30, 2017. See below for the many benefits to becoming an ISEK Member.

Benefits

In addition to the connections you will make with fellow members, your ISEK membership also includes access to the following:

- Ability to register for the Biennial ISEK Congress at reduced registration rates
- Ability to submit abstracts for the ISEK Congress
- Ability to participate in society elections
- Opportunities for professional development and networking
- Regular email updates and notices

To become an ISEK Member please visit us at the registration desk today.

Congress Venue

Hyatt Regency Chicago
151 East Wacker Drive
Chicago

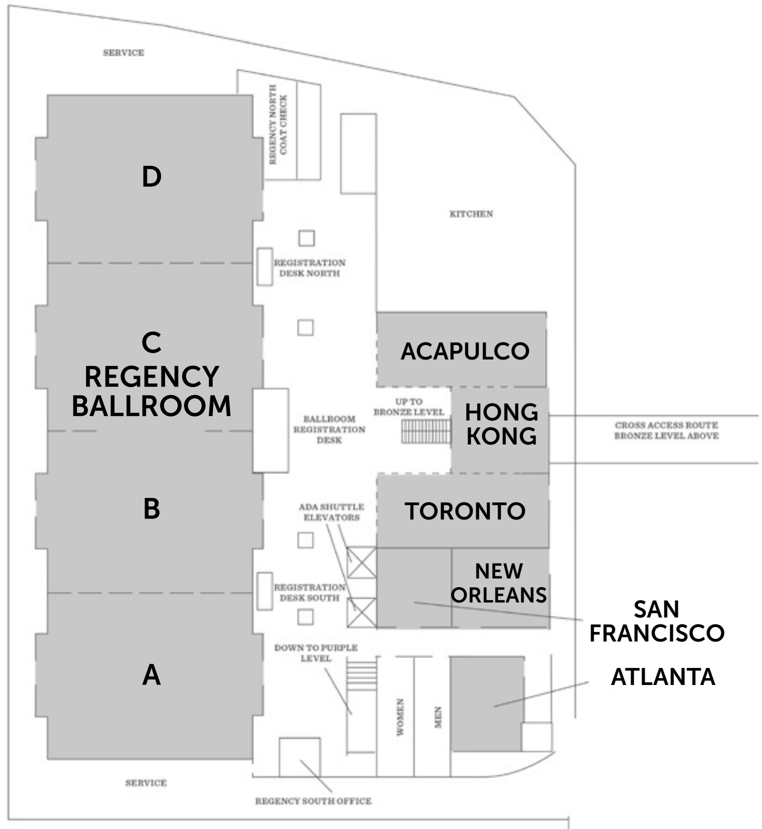
Check in: 3:00pm
Check out: 12:00pm

All congress sessions will take place in this location. The opening reception and banquet will be held offsite. For further details on these social events, please visit page vii

Hotel Floor Plans

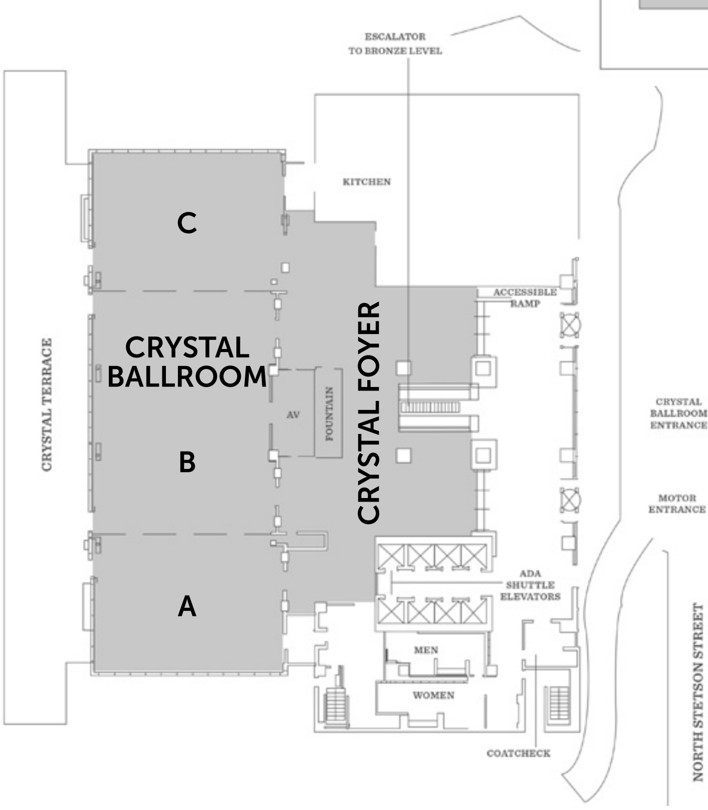
REGENCY BALLROOM
(West Tower, Gold Level)

All sessions will take place in the Regency Ballroom



CRYSTAL BALLROOM
(West Tower, Green Level)

Exhibitor and Poster Hall



For Poster and Exhibitor map, please see page 32

Registration

ANNUAL CONGRESS

Annual Congress registration fees include access to all sessions including symposium, individual, and poster sessions. Registration also includes daily refreshment breaks, grazing lunches, the Opening Reception at the Rehabilitation Institute of Chicago, the Congress Banquet at the Mid America Club, and the Closing Reception sponsored by ISB.

ADDITIONAL TICKETS

Tickets can be purchased separately for your guests for the Opening Reception, and Banquet. These additional tickets can be purchased from the staff at ISEK's Registration Desk.

Name Badges

Your name badge is your admission ticket to the conference sessions, coffee breaks, meals, receptions and banquet. Please wear it at all times. To help identify and mentor our future investigators, student delegates have red edged badges. All other delegates have clear badges. ISEK Council Members, Exhibitors and Staff will be identified by appropriate ribbons. At the end of the Congress we ask that you recycle your name badge in one of the name badge recycling stations that will be set out, or leave it at the Registration Desk.

Dress Code

Dress for the ISEK Congress is casual. Further information on dress code for the social events can be found on page vii

Registration and Information Desk Hours

If you need assistance during the Congress, please visit the Registration Desk.

The ISEK Registration and Information Desk, located outside the Regency Ballroom, will be open during the following dates and times:

Tuesday, July 5	07:00 – 17:30
Wednesday, July 6	07:30 – 18:00
Thursday, July 7	07:30 – 18:00
Friday, July 8	07:30 – 17:00

Poster Information

There are three Poster Sessions during the Congress and posters have been allocated to one of the sessions based on poster themes. Poster presenters must set-up and remove their posters during the following times.

POSTER SESSION 1 – WEDNESDAY, JULY 6

Set-up: Wednesday, July 6, between 07:00 and 09:30

Remove: Wednesday, July 6, between 18:30 and 19:00

POSTER SESSION 2 – THURSDAY, JULY 7

Set-up: Thursday, July 7, between 07:00 and 09:00

Remove: Thursday, July 7, between 18:00 and 18:30

POSTER SESSION 3 – FRIDAY, JULY 8

Set-up: Friday, July 8, between 07:00 and 09:30

Remove: Friday, July 8, between 13:30 and 14:00

GENERAL CONGRESS INFORMATION

Information on Poster Authors, Poster Numbers and Poster Titles begins on page 38. For a complete copy of all the poster abstracts, digital copies can be downloaded from the ISEK website

Easy reference Poster floor plans for each session can be found on the inside back cover of this program.

Staff

ISEK staff from Podium Conference Management Ltd can be identified by orange ribbons on their name badges. Feel free to ask anyone of our staff for assistance. For immediate assistance please visit us at the Registration Desk.

Internet Services

ISEK is providing internet access as part of the 2016 Congress registration. The wireless code for the duration of the conference is

Network name **Hyatt Conference**

Password **ISEK2016**

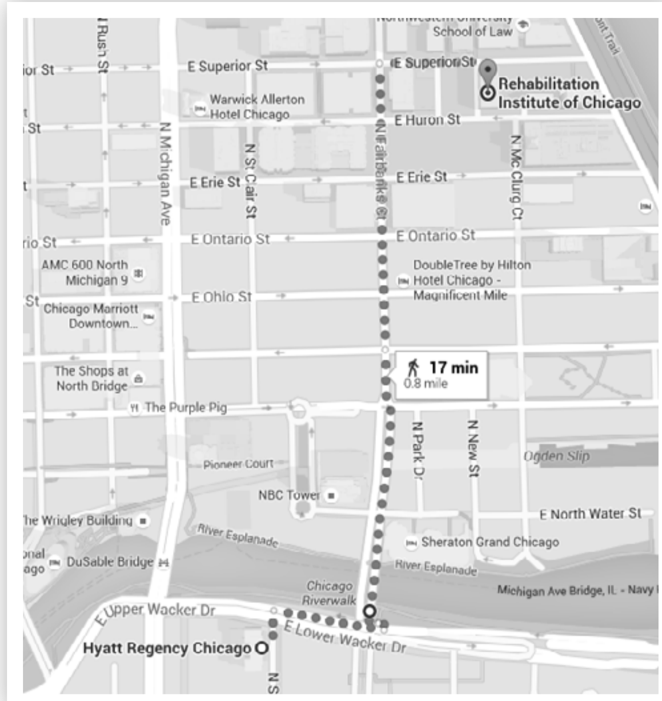
If you require assistance, please visit the registration desk and we will endeavour to assist you.

Bedrooms booked through ISEK's group room block include complimentary standard internet. Depending on signal strength, this service will allow connection throughout the hotel's public spaces. Additional connection information is available through the hotel's front desk.

TUESDAY, JULY 5

18:00 – 20:00 **Opening Reception**

Location:
Rehabilitation Institute
of Chicago



The opening reception will be held at the RIC, and will offer attendees the chance to tour the brand new RIC facility, currently in construction.
As a delegate this event is included in your registration fee. If you plan to bring an accompanying guest to the reception, you can purchase an additional ticket through your registration or the registration desk for $35USD.
For directions, please see map. If you require assistance getting to the venue, please come and see us at the registration desk

Dress Code: Casual

THURSDAY, JULY 7

19:30 – 23:00 **Conference Banquet**

Location: The Mid America Club
200 East Randolph Drive,
80th Floor, Aon Center,
Chicago, IL 60601

This beautiful venue has panoramic views of the Chicago skyline, and is just a short walk from the Congress Hotel. As a Congress delegate, this banquet is included in your registration. If you plan to bring an accompanying guest to the banquet, you can purchase an additional ticket through your registration or at the registration desk for $75USD.

Dress code for Mid America Club: Business Casual - No T-Shirts, Tank Tops, Tank-style Undershirts or Halter-Tops are allowed, regardless of logo or imprint. Tennis Shoes, Sneakers (unless worn for medical reasons), Flip-Flops and other casual shoes are not permitted. Shorts, Sweat Suits, Jogging/Tennis and other athletic attire are never permitted.

FRIDAY, JULY 8

17:00 – 18:00 **Closing Drinks Reception**

Sponsored by ISB
Location: The Regency Ballroom Foyer
Dress Code: Casual

ARCHITECTURE FOUNDATION MUST-SEE CHICAGO WALKING TOUR

Tuesday July 5, 2016 2:00pm – 3:30pm

The tour begins at 2:00pm sharp at the Chicago Architecture Foundation, and wraps up at the intersection of Michigan and Chicago Avenues, the heart of the Magnificent Mile.

Ticket holders are responsible for their own travel arrangements to the CAF building to begin the tour. To travel by foot from the hotel, walk south on N Stetson Ave away from the river. Turn right onto E Randolf St (when you reach the Harris Theatre), then left onto N Michigan Ave. You'll pass the Art Institute of Chicago on your left. Alternatively, it's about 4 minutes in a taxi.

CHICAGO WHITE SOX BASEBALL GAME

The game begins at 7:10pm on Wednesday July 6th

If you've prepaid for a ticket, please pick these up upon registration. If you would like to purchase a ticket onsite, please visit the registration desk to purchase a ticket for $21 (based on availability)

US Cellular Field – home of the Chicago White Sox!

333 W 35th Street
Chicago, IL 60616

Driving

If you are driving to US Cellular Field, please note depending on traffic, it will take approximately 10 – 15 minutes to drive the 9 miles to the field.

Follow US 41S, merge onto I55 South, merge onto I90(LOCAL)E/I94 Dan Ryan Expressway S

Take Exit 55A and follow the signs to US Cellular Field and use 35th Street exit. If 35th Street Exit is temporarily closed due to heavy traffic, proceed to 39th Street Exit.

More information on parking and different routes can be found at *http://chicago.whitesox.mlb.com/cws/ballpark/transportation/index.jsp?content=automobile*

Please note that parking is $20 and credit cards are accepted in all White Sox parking lots.

Public Transport

From any Red Line subway station along State Street (Chicago, Grand, Lake, Washington, Monroe or Jackson) board a southbound Red Line 95th/Dan Ryan train and get off at the Sox/35th Red Line Stop. Once out of the station, cross Wentworth Street and enter the stadium at the appropriate gate entrance. Please note that the Lake Street Station is the closest to the Hyatt Regency and is approximately 4 blocks (10 minute walk) from the hotel. The entire trip is estimated to take 35 minutes.

Taxi Service

Following the game if you are interested in catching a taxi cab back to the Hyatt Regency, cabs will be on 35th Street between Gates 4 and 6.

ARCHITECTURE FOUNDATION RIVER CRUISE

Various departures are available

There is a 10% discount for congress attendees. You can download/print this coupon from the excursions page on the ISEK excursions webpage.

Tuesday, July 5

Please check the individual start and end times outlined below

08:00 – 12:00
(Regency A)

WORKSHOP 1A:

Applications of Motor Unit Decomposition Technologies in Disease States

The first part of this workshop will focus on technologies for motor unit decomposition and their applications in diagnostics and rehabilitation. Methods for extraction of neural codes from multichannel surface and intramuscular EMG will be presented, along with their recent advances. We will further disclose the assumptions and constraints involved in EMG decomposition and motor unit identification in various applications; both theoretical and experimental issues will be considered, including the methods for assessing decomposition accuracy, real-time motor unit tracking and dynamic EMG decomposition. Presentations will be supplemented by a demonstration of the decomposition process on real signals. The first part of the workshop will include the following three presentations:

Dario Farina, The Institute of Neurorehabilitation Systems, University Medical Center Göttingen, Germany

Introduction to multichannel EMG decomposition and applications

Aleš Holobar, University of Maribor, Slovenia

Motor unit identification in different use case scenarios: isometric, real-time and dynamic conditions

Francesco Negro, The Institute of Neurorehabilitation Systems, University Medical Center Göttingen, Germany

Motor unit identification and validation in high-density multichannel intramuscular EMG signals

The second part of this workshop will provide in depth discussion of how decomposition algorithms can be used to better understand motor control following stroke, and how anomalies in motor unit firing contribute to muscle weakness. Applications of different motor unit decomposition protocols to data obtained from EMG grid recordings in pathologic states will be discussed, most notably hemispheric stroke and the origins of muscle weakness for voluntary contractions. This section of the workshop will include the following three presentations:

Nina Suresh, Rehabilitation Institute of Chicago, USA

Changes in motor unit firing rate profiles in paretic muscles of stroke survivors

Xiaogang Hu, North Carolina State/University of North Carolina, USA

Putting the pieces together – simulations of motor unit rate and recruitment profiles to predict muscle force output in paretic muscles of stroke survivors

Zev Rymer, Rehabilitation Institute of Chicago, USA

Decomposition methods reveal anomalies in motor unit recruitment during voluntary muscle activation in stroke survivors

13:00 – 15:00 *(Regency A)*

WORKSHOP 1B:

ISB Working Group on Motor Control in Biomechanics

Organizer:
Dr. Paola Contessa, Delsys Inc., USA

Session Chairs:
Prof. Carlo J. De Luca, Boston University and Delsys Inc., USA,
Dr. Paola Contessa, Delsys Inc., USA

13:00 – 13:20 Opening – **Prof. Carlo J. De Luca**, Boston University & Delsys Inc., USA

13:20 – 13:45 **Dr. Joshua C. Kline**, Delsys Inc., USA
The empirically unsupported practice of estimating common synaptic inputs

13:45 – 14:10 **Prof. Andrea D'Avella**, University of Messina and Santa Lucia Foundation, Italy
Muscle synergies: biomechanical epiphenomenon or neural control strategy?

14:10 – 14:35 **Prof. Paul Hodges**, University of Queensland, Australia
Probing muscle coordination with electromyography: Lessons from adaptation to pain

14:35 – 15:00 **Prof. Patrick E. Crago**, Case Western Reserve University, USA
Augmenting voluntary reach and grasp in stroke survivors by functional electrical stimulation

10:00 – 15:00 *(Regency B)*

WORKSHOP 2:

3D Multiscale modeling of neuromuscular mechanics

This workshop will contain a mixture of lecture and interactive activities designed so that the workshop participants will have the opportunity to

1. Obtain a general understanding of the modeling concepts relevant to constructing 3D multi-scale models including an overview of the available software tools, and

2. Engage in an open discussion of the applications areas where 3D multi-scale neuromuscular models may be most relevant and the technical developments required to realize their full potential.

Presenters and Organisers

Sherif M. Elbasiouny, Wright State University, USA

Oliver Röhrle, University of Stuttgart, Germany

Silvia Salinas Blemker, University of Virginia, USA

Yasin Dhaher, Rehabilitation Institute of Chicago and Northwestern University, USA

08:30 – 14:30 (Regency C)

WORKSHOP 3:

Implantable technologies for Electrophysiological Recording and Stimulation

Organizers:

Levi Hargrove, Rehabilitation Institute of Chicago and Northwestern University, USA

Elliott Rouse, Rehabilitation Institute of Chicago and Northwestern University, USA

Implantable technologies for neural stimulation and recording have tremendous potential for broadening the impact of electrophysiological research. Though there has been much progress, particularly in the areas of miniaturization and reliability, the current state of the art is also characterized a diversity of approaches. This workshop will provide an historical overview of the field that addresses some of this diversity including the solutions each provides and the challenges encountered. It will also provide an overview of state-of-the-art and emerging technologies, and discuss future applications these are expected to enable. In addition to the technical and applied aspects of implantable technologies, the workshop will also provide an open forum for discussing the risk-benefit trade-offs of these approaches when compared to non-invasive technologies and the regulatory issues required to translate the most promising technologies from the laboratory to the clinic.

08:30 – 08:45 Welcome and Overview

08:45 – 09:30 ***The BioNode: A Flexible and Robust Wireless Implant Platform***
Pedro Irazoqui, Director of the Center for Implantable Devices, Purdue University, USA

09:30 – 10:00 ***Coffee Break***

10:00 – 10:30 ***Natural sensory feedback for modulation of phantom limb pain***
Winnie Jensen, Director of the 'Neural Engineering and Neurophysiology' Research Group, Aalborg University, Denmark

10:30 – 11:15 ***Simultaneous and Proportional Control of Powered Prosthesis using Intramuscular***
Levi Hargrove, Director of the Neural Engineering for Prosthetics and Orthotics Laboratory, Rehabilitation Institute of Chicago, USA

11:15 – 12:00 ***Neural Control Sources for Dextrous Finger Movements***
Cynthia Chestek, Director of the Cortical Neural Prosthetics Lab, University of Michigan, USA

08:00 – 15:00 (Regency D)

WORKSHOP 4:

Investigation of muscle physiology, force generation and tissue dynamics through imaging. Challenges for estimating muscle force and properties

08:00 Introduction

08:05 **Rick Lieber**[1,2]:
Passive muscle tension: Poorly understood but critically important"

08:35	**Tom Sandercock** *Direct measures of active force and stiffness in animals: Does this set reasonable limits to specific tension in human models?*
09:00	**Huub Maas**[3]: ***Myofascial force transmission; effects on estimates of specific muscle force***
	[1]Rehabilitation Institute of Chicago, USA; [2]Northwestern University, USA; [3]VU University Amsterdam, Netherlands
09:30	**Coffee break**
10:00	**Ian Loram**[1]: ***The information content of muscle, from motor unit to individual muscle, to complex muscle groups, available through US imaging***
10.18	**Pete Harding**[1] and **Ian Loram**[1]: ***Application of statistical parametric maps to analysis of ultrafast ultrasound***
10.36	**Ryan Cunningham**[1]: ***The real-time extraction of muscle information from ultrasound using advanced segmentation methods***
10:54	**Ryan Cunningham**[1]: ***The extraction of active and passive muscle features from ultrasound using deep learning***
11:12	**Emma Hodson-Tole**[1]: ***Characterising Involuntary Muscle Activity in Ultrasound Imaging: Can we quantify physical motor unit properties in vivo?***
11:30	**James Wakeling**[2]: ***3D analysis of muscle fascicles using ultrasound***
	[1]Manchester Metropolitan University, UK; [2]Simon Fraser University, Canada
12:00	**Lunch break** + Demonstrations from Block 2.
13:00	**Rick Lieber**[1,2]: ***Supercontinuum lasers for measurements of muscle structure and metabolism***
13:15	**Francois Hug**[3]: ***Elastography for Muscle Biomechanics: Toward the Estimation of Individual Muscle Force***
13:45	**Dieter Klatt**[4]: ***Magnetic Resonance Elastography for the Assessment of the Mechanical Properties of Skeletal Muscle***
14:15	**Bart Bolsterlee**[5]: ***Diffusion tensor imaging of human skeletal muscle: techniques, applications and challenges***
	[1]Rehabilitation Institute of Chicago, USA; [2]Northwestern University, USA; [3]Université de Nantes, France; [4]University of Illinois, USA; [5]Neuroscience Research Australia, Australia

08:00 – 15:00 *(Toronto)*

WORKSHOP 5:

1. ***Insight into neural mechanisms of afferent pathways learned from neural recordings, mathematical modeling and real-time neuromorphic simulations***

   Chair: **Winfred Mugge**

   Presenters:
   Andrew Pruszynski, Western University, USA;
   Charles J Heckman, Northwestern University, USA;
   Jerry Loeb, University of Southern California, USA;
   Kian Jalaleddini and **Francisco Valero-Cuevas**,
   University of Southern California, USA

2. ***Understanding healthy and pathologic reflex functions***

   Chair: **Francisco Valero-Cuevas**, University of Southern California. USA

   Presenters:
   Michael Dimitriou, Umeå University, Sweden;
   Jurriaan H. de Groot, Leiden University Medical Center; Netherlands; **Claire Honeycutt**, Arizona State University, USA

3. ***Contributions of muscle afferents to the regulation of single- and multi-joint rapid responses***

   Chair: **Jonathan Shemmell**, University of Otago, New Zealand

   Presenters:
   Isaac Kurtzer, New York Institute of Technology, USA;
   Robert E. Kearney, McGill University, Canada;
   Winfred Mugge and **Alfred C. Schouten**,
   Delft University of Technology, Netherlands

Panel Discussion (0.5 hours) - 1 or 2 speakers from every session (5/6 in total)

15:30 – 17:45 *(Regency Ballroom A)*

DELSYS WORKSHOP

Rethinking Research in the Era of Wearable Sensors: Quality of Movement Measurement

The workshop lead by **P. Contessa,** Ph.D and **J. Kline,** Ph.D will focus on Quality of Movement Measurement (QMM), scientific instruments in use today, and why and how they are relevant to Movement Measurement Research.

Expert speakers **J. Richards,** Ph.D (University of Central Lancashire) and **J. DeFreitas,** Ph.D. (Oklahoma State University) will present scientific data on applications of the Trigno IM (EMG and IMU) sensor and dEMG system in research and clinical applications, with a focus on their role in constructing intervention strategies vital to QMM.

Who should attend? Researchers that are interested in using research instruments to: **1|** look behind the traditional skeletal models, and **2|** looking beyond the utility of sEMG signals to define new neuromuscular measurements in assessment and intervention strategies.

Research-grade Instruments and Realities: Era of Wearable Sensors

The workshop will be opened w. a brief introduction on research grade-instruments, factors a researcher should consider.

Expert Presenters:

Using Trigno (EMG and IMU) sensors: Looking at the data behind the skeletal models and its clinical/practical application

Presenter: **Dr. Jim Richards,** Professor of Biomechanics, Research Lead for the Allied Health Research Unit, *University of Central Lancashire, UK*

The use of IMU sensors is now commonplace within kinesiology research, and clearly has significant potential to be used in clinical and sports practice environments. Much of the work to date has focussed on using biomechanical models, however there is still a significant amount of useful data to be obtained by considered gyroscope and accelerometer data, especially when combined with EMG data. This talk will consider the aspects of angular velocity and linear acceleration and how these can be used to determine the clinical effect of different interventions. This will include a demonstration of the level of agreement between angular velocity data obtained from camera based systems versus IM sensors. In addition, how these can subsequently be used to determine quality on movement and changes in control due to proprioceptive interventions for joint stability such as knee taping and bracing. Key papers have shown that changes in joint biomechanics, including improvements in coronal and transverse plane stability and neuromuscular control, are possible in normal subjects and subjects who suffer from knee pain and instability. However, to date this has been largely only investigated with 3D motion camera systems. This talk will demonstrate how clinically important changes in movement control, joint stability and muscle activity may also be assessed in clinic with IM/EMG sensors.

Key Words: EMG +IMU Sensors, Quality of Movement Measurement, Instability, Taping, Bracing, Neuromuscular Control.

Utilization of dEMG for assessing motor unit action potential morphology: Assessment and intervention strategies

Presenter: **Dr. Jason M. DeFreitas,** *Oklahoma State University (USA)*

For decades, assessment of motor unit firing behaviour and action potential morphology has been a standard part of clinical neurological exams. Depending on the symptoms, this test often consists of the insertion of a needle EMG electrode (typically 22-30 gauge) into the belly of a muscle. Despite its frequent use, research on action potential morphology has been primarily focused only on its diagnostic utility. However, recent advancements in the decomposition of surface EMG (dEMG) technology has not only allowed for motor unit action potentials to be examined non-invasively (i.e. no needles), but has broadened its potential utility. Recent findings will be presented that demonstrate the dEMG system's ability to assess motor unit specific hypertrophy as well as aging- or disease-related atrophy without the need for biopsies. Furthermore, future research studies attempting to improve neuropathy and myopathy diagnostics will also be discussed.

Key Words: Motor Unit morphology, Needle EMG, Muscle Hypertrophy, Neuropathy, Quality of Movement Measurement (QMM)

NOTES

Tuesday, July 5

Pre-Conference Workshops – Details can be found on page 1

OPENING OF ISEK CONGRESS 2016

18:00 – 20:00 **OPENING RECEPTION**
Rehabilitation Institute of Chicago (RIC)
345 E Superior St, Chicago, IL 60611 (see page vii for walking directions)

Wednesday, July 6

08:00 – 08:30 *(Regency Ballroom AB)*
OPENING REMARKS
Rick Lieber, Senior Vice President & Chief Scientific Officer, Rehabilitation Institute of Chicago

08:30 – 09:30 *(Regency Ballroom AB)*
KEYNOTE PRESENTATION
John Rogers, *University of Illinois*
Epidermal Electronics for Electrophysiological Kinesiology
Chair: **Eric Perreault,** *Northwestern University*

09:30 – 10:00 **BREAK** (CRYSTAL BALLROOM)

10:00 – 11:30 **PARALLEL SESSIONS**

S.1. *(Regency Ballroom A)*
Neuromechanics of Human Locomotor Stability: Theoretical Insights and Clinical Applications
Chairs: **James Finley**, *University of Southern California*
Keith Gordon, *Northwestern University*

Inter-limb cutaneous feedback in walking balance: Early responses at the ankle to rapid light touch displacement at the fingertip during walking
John Misiaszek[1], Tania Shiva[1] | [1]*University of Alberta*

Perturbation Based Gait Training May Improve the Tradeoff of Stability and Maneuverability in Patients with Lower Limb Injury
Riley Sheehan[1], Jason Wilken[1], Jonathan Dingwell[2]
[1]*Military Performance Lab, Center for the Intrepid,* [2]*University of Texas at Austin*

Post-stroke deficits in a mediolateral gait stabilization strategy (and a possible intervention)
Jesse Dean[1] | [1]*Medical University of South Carolina*

The effect of balance perturbations after myelopathy related sensory deficits on cortical oscillations during walking
Joseph Lee[1], Brian Schmit[1] | [1]*Marquette University*

Cortical Correlates of Locomotor Adaptation to Perturbations of Symmetry
James Finley[1] | [1]*University of Southern California*

System Identification of the Human Locomotion Control System and Energy-optimal Feedback Control
Varun Joshi[1], Barrett Clark[1], Nidhi Seethapathi[1], Yang Wang[2], **Manoj Srinivasan**[1]
[1]*The Ohio State University,* [2]*Caterpillar*

S.2. ***Motor Unit Control***
(Regency Ballroom B) Chairs: **Joshua Kline**, *Delsys Inc.*
Patrick Crago, *Case Western Reserve University*

Synchronization studies require accurate motor unit firings and robust statistical tests
Joshua Kline[1], Carlo De Luca[1] | [1]*Delsys, Inc*

Assessing Motor Unit Pool Control Properties in Aging using Surface Electromyography
Xiaogang Hu[1], William Rymer[2], Nina Suresh[2] | [1]*University of North Carolina-Chapel Hill,* [2]*Rehabilitation Institute of Chicago*

Motor unit coherence and synchronization in response to sustained isometric contraction of the first dorsal interosseous muscle
Lara McManus[1], Xiaogang Hu[2], William Rymer[3], Nina Suresh[4], **Madeleine Lowery[1]**
[1]*University College Dublin,* [2]*University of North Carolina-Chapel Hill and North Carolina State University ,* [3]*Northwestern University,* [4]*Rehabilitation Institute of Chicago*

Homogeneity of the Relationship between Motor Unit Recruitment Thresholds versus Derecruitment Thresholds across Force Levels and the Lifespan
Matt Stock[1], Jacob Mota[1] | [1]*Texas Tech University*

Transposed firing activation of motor units during oscillatory contractions
Paola Contessa[1], Joshua Kline[1], Carlo De Luca[2] | [1]*Delsys Inc,* [2]*Boston University, Delsys Inc*

Biomechanical Benefits of the Onion-Skin Scheme of Motor Unit Firing
Carlo De Luca[1], Paola Contessa[2] | [1]*Boston University/Delsys Inc,* [2]*Delsys Inc*

O.1. ***Rehabilitation Technologies I***
(Regency Ballroom C) Chairs: **Paolo Bonato,** *Harvard University*
Deanne Gates, *University of Michigan*

O.1.1 A new wearable exoskeleton device that controls knee motion in individuals after stroke
Shihomi Kawasaki[1], Koji Ohata[1], Tadao Tsuboyama[1], Yuichi Sawada[2], Yoshiyuki Higashi[2]
[1]*Graduate School of Medicine, Kyoto University,* [2]*Kyoto Institute of Technology*

O.1.2. A Novel Device for Functional Strength Training during Gait: Evidence from Healthy and Stroke Subjects
Edward Washabaugh[1], Edward Claflin[1], Richard Gillespie[1], Chandramouli Krishnan[1] | [1]*University of Michigan*

O.1.3 Gait Rehabilitation in Paediatric Population through a Novel Robotic Platform: Pilot study
Cristina Baruón[1], **Eduardo Rocon[1]** | [1]*CSIC*

O.1.4 The kinematic change for inverted pendulum during stance phase with assist of hip movement in individuals after stroke.
Koji Ohata[1], Shihomi Kawasaki[1], Yasushi Ikeuchi[2], Yosuke Nagata[2], Toru Takenaka[2]
[1]*Graduate school of Medicine, Kyoto University,* [2]*Honda R&D Co., Ltd.*

O.1.5 Measuring balance control on a treadmill: no need for shear forces
Ingrid Schut[1], Jolanda Roelofs[2], Jantsje Pasma[1], Herman van der Kooij[1], Vivian Weerdesteyn[2], Alfred Schouten[1] | [1]*Delft University of Technology,* [2]*Radboud university medical center*

O.1.6 The Effect that Joint Mobilization has on Propriospinal Reflexes and Pain
James Agostinucci[1], John McLinden[1] | [1]*University of Rhode Island*

O.2. ***Neuromechanics I***
(Regency Ballroom D) Chairs: **Daniel Ludvig**, *University of Montreal*
Karl Zelik, *Northwestern University*

O.2.1 Task dependancy in Sensorimotor Training: Influence of free bipedal and unipedal stance on variance of soleus H-reflex amplitudes
Gunnar Wahmkow[1], Tilman Engel[1], Steffen Müller[1], Eduardo Martinez-Valdez[1], Kaplick Hannes[1], Frank Mayer[1] | [1]*Potsdam University*

O.2.2 Trunk Muscle Reflexes Are Elicited by Small Continuous Perturbations
Daniel Ludvig[1], Christian Larivière[2] | [1]University of Montreal, [2]Occupational Health and Safety Research Institute Robert-Sauvé (IRSST)

O.2.3 Heteronymous models are needed to describe shoulder stretch reflexes
M. Hongchul Sohn[1], Emma Baillargeon[1], David Lipps[2], Eric Perreault[3] | [1]*Northwestern University,* [2]*University of Michigan,* [3]*Northwestern University and Rehabilitation Institute of Chicago*

O.2.4 Nonlinear connectivity in the human stretch reflex revealed by nonlinear phase coherence and multisine perturbations
Yuan Yang[1], Teodoro Solis-Escalante[1], Jun Yao[2], Frans van der Helm[1], Julius Dewald[2], Alfred Schouten[1] | [1]*Delft University of Technology,* [2]*Northwestern University*

O.2.5 Peri-patellar taps elicit regional stretch reflexes in the human vastus medialis
Alessio Gallina[1], Jean-Sébastien Blouin[1], Tanya Ivanova[1], S Jayne Garland[2] | [1]*University of British Columbia,* [2]*University of Western Ontario*

O.2.6 Evidence of Invariance in the Lower Leg Muscle?s Response due to Stretch Reflex Excitation during Movement.
Diego Guarin[1], Robert Kearney[1] | [1]*McGill University*

11:30 - 13:00 PARALLEL SESSIONS

O.3. ***EMG: modeling***
(Regency Ballroom A) Chairs: **Madeleine Lowery**, *University College Dublin*
Ted Clancy, *Worcester Polytechnic Institute*

O.3.1 Comparison of EMG Feature Projection Techniques for Force Estimation
Muhammad Asim Waris[1], Winnie Jensen[1], Kevin Englehart[2], **Ernest Kamavuako[1]**
[1]*Aalborg University,* [2]*University of New Brunswick*

O.3.2 Periods of non-stationarity indicate motor unit recruitment in the tibialis anterior muscle of young healthy adults
Shanette Go[1], William Litchy[1], Carlos Mantilla[1], Gary Sieck[1], Kenton Kaufman[1] | [1]*Mayo Clinic*

O.3.3 Two Degrees of Freedom EMG-Force at the Wrist in Able-Bodied Subjects Using a Minimum Number of Electrodes: Pilot Testing of Limb-Absent Subjects
Edward Clancy[1], Carlos Martinez-Luna[2], Marek Wartenberg[1], Todd Farrell[2] | [1]*Worcester Polytechnic Institute,* [2]*Liberating Technologies, Inc.*

O.3.4 A comparison of Spike Shape Measures from Surface and Indwelling Electromyography during Elbow Flexion Isometric Ramp Contractions
Lara Green[1], Anita Christie[2], J. Greig Inglis[1], David Gabriel[1] | [1]*Brock University,* [2]*University of Oregon*

O.3.5 On the Usability of Rejection Capable Support Vector Machines in an Online Virtual Targeting Task

Jason Robertson[1], Kevin Englehart[1], Erik Scheme[1] | [1]*University of New Brunswick*

O.3.6 Towards Improving the Training of Pattern Recognition Based Myoelectric Control

Kadie Wright[1], Kevin Englehart[1], Erik Scheme[1] | [1]*Institute of Biomedical Engineering*

O.4. ***Rehabilitation Technologies II***

(Regency Ballroom B)

Chairs: **Patrick Crago,** *Case Western Reserve University*

Julius Dewald, *Northwestern University*

O.4.1 Cranial Nerve Non-Invasive Neuromodulation for Symptomatic Treatment of Mild and Moderate Traumatic Brain Injury - Effects on Muscle Coordination Patterns during Walking

Samuel Acuña[1], Mitchell Tyler[1], Yuri Danilov[1], Darryl Thelen[1] | [1]*University of Wisconsin-Madison*

O.4.2 What does the CNS see during electrically stimulated muscle contractions?

Patrick Crago[1] | [1]*Case Western Reserve University*

O.4.3 Does the distance between electrodes markedly affect the knee extension torque elicited in tetanic, stimulated contractions?

Taian Vieira[1], Laura Gastaldi[1], Alberto Botter[1] | [1]*Politecnico di Torino*

O.4.4 Sensory and Motor Thresholds for Surface Electrical Stimulation of Median and Ulnar Nerves at Elbow for Sensory Feedback

Marjolein Eiselina Thijssen[1], Petr Sipka[1], Søren Larsen[1], Mai Kristiane Thomsen[1], **Eugen Romulus Lontis[1]**, Winnie Jensen[1] | [1]*Aalborg University*

O.4.5 The effect of rehabilitation with the neuromuscular electrical stimulation after femoral neck fracture surgery -Short term intervention reports-

Daisuke Bai[1], Mitsunori Tokuda[1], Yuki Fujimori[1], Yuki Kameguchi[1], Munehiro Ogawa[2], Yasuhito Tanaka[2] | [1]*Heisei Memorial Hospital,* [2]*Nara Medical University*

O.4.6 The cortical adaptation monitoring system for leg press machine with FES induced biofeedback

Misato Kasuya[1], Mai Nozakura[1], Soichiro Morishita[1], Yinlai Jiang[1], Masao Sugi[1], Hiroshi Yokoi[1], **Ryu Kato[2]** | [1]*The University of Electro-Communications,* [2]*Yokohama National University*

O.5. ***Neuromechanics II***

(Regency Ballroom C)

Chairs: **Minoru "Shino" Shinohara**, *Georgia Tech*

Karl Zelik, *Northwestern University*

O.5.1 Effect of Lower Extremity Efforts on Involuntary Upper Extremity Activity in Chronic Hemiparetic Stroke: Preliminary Findings

Rachel Hawe[1], Jules Dewald[1] | [1]*Northwestern University*

O.5.2 Variability in neuromotor control of the musculoskeletal system dynamics: a stochastic modelling approach.

Bart van Veen[1], Saulo Martelli[2], Claudia Mazzà[1], Erkki Somersalo[3], Daniela Calvetti[3], Marco Viceconti[1] | [1]*University of Sheffield,* [2]*Flinders University,* [3]*Case Western Reserve University*

O.5.3 From muscle-tendon to whole-body dynamics: towards a multi-scale empirical understanding of human movement biomechanics

Karl Zelik[1] | [1]*Vanderbilt University*

O.5.4 The same library of muscle synergies are shared across diverse locomotor tasks

Jessica Allen[1], Andrew Sawers[2], Lena Ting[1] | [1]*Emory University,* [2]*University of Illinois at Chicago*

O.5.5 Decreasing the lumbar flexion moment induces earlier onset of flexion relaxation

Derek Zwambag[1], Diana De Carvalho[2], Stephen Brown[1] | [1]*University of Guelph,* [2]*Memorial University of Newfoundland*

O.5.6 Estimation of Ankle Impedance During Walking on a Slippery Surface

Mariah Whitmore[1], Levi Hargrove[1], Eric Perreault[1] | [1]*Northwestern University*

O.6. ***Motor Units I***
(Regency Ballroom D)
Chairs: **Kevin Keenan**, *University of Wisconsin*
Paola Contessa, *Boston University*

O.6.1 Motor units in the human medial gastrocnemius muscle are not spatially localized or functionally grouped

Martin Héroux[1], Harrison Brown[2], John Inglis[2], Gunther Siegmund[3], Jean-Sébastien Blouin[2]
[1]*Neuroscience Research Australia,* [2]*University of British Columbia,* [3]*MEA Forensic Engineers & Scientists*

O.6.2 Motor Unit Action Potential Clustering

Michael Asmussen[1], Vinzenz von Tscharner[1], Benno Nigg[1] | [1]*Univeristy of Calgary*

O.6.3 EMG envelope and tension oscillations during steady fine motor control

Claudio Orizio[1], Francesco Negro[2], Marta Cogliati[1], Anna Castronovo[2], Dario Farina[2]
[1]University of Brescia, [2]University Medical Center Göttingen

O.6.4 Using the Size Principle to Model Peripheral Muscle Fatigue

Jim Potvin[1], Andrew Fuglevand[2] | [1]*McMaster University,* [2]*University of Arizona*

O.6.5 Features for tracking spatial intra-cortical, electrophysiological changes in a rat model of ischemic stroke

Rasmus Nielsen[1], **Winnie Jensen[1]** | [1]*Sensory-Motor Interaction*

13:00 – 14:00	**LUNCH, POSTERS & EXHIBITORS** (CRYSTAL BALLROOM)
14:00 – 15:00 (*Regency Ballroom AB)*	**KEYNOTE PRESENTATION** ***Why is it important to use EMG in Clinical research of musculoskeletal disorders*** **Birgit Juul-Kristensen**, *University of Southern Denmark* Chair: **Karen Søgaard,** *University of Southern Denmark*
15:00 – 15:30	**BREAK** (CRYSTAL BALLROOM)
15:30 – 17:00	**PARALLEL SESSIONS**

S.3. (Regency Ballroom A) ***Muscle mechanics and neural control determining fine hand-motor tasks***

Chairs: **Dick F. Stegeman**, *Radboud University Medical Centre*
Huub Maas, *VU University*

Mechanical factors limiting finger independence
Huub Maas[1], Nathalie van Beek[1], Josien van den Noort[2], Dick Stegeman[3]
[1]*Vrije Universiteit Amsterdam,* [2]*VU University medical center,* [3]*Radboud University Medical Centre*

The Effect of the Subsynovial Connective Tissue in the Carpal Tunnel On Finger Motion In Health And Disease
Peter Amadio[1] | [1]*Mayo Clinic*

Neuromuscular control of extrinsic flexors and extensors during single finger movements
Nathalie van Beek[1], Dick Stegeman[2], Josien van den Noort[3], DirkJan Veeger[1], Huub Maas[1]
[1]*Vrije universiteit Amsterdam,* [2]*Radboud University Medical Centre,* [3]*VU University medical center*

Base vectors in complex finger movements
Sigrid Dupan[1], Naveed Ejaz[2], Dick Stegeman[1], Joern Diedrichsen[2] | [1]*Donders Institute for Brain, Cognition, and Behaviour,* [2]*The Brain and Mind Institute*

Correlated deficits in bi-lateral hand function following unilateral stroke
Naveed Ejaz[1], Jing Xu[2], Benjamin Hertler[3], Meret Branscheidt[2], Mario Widmer[3], Nathan Kim[2], Michelle Harran[4], Juan Cortes[4], Andreia Faria[2], Pablo Celnik[2], Tomoko Kitago[4], Andreas Luft[4], John Krakauer[2], Jörn Diedrichsen[5] | [1]*University College London,* [2]*Johns Hopkins University,* [3]*University of Zürich,* [4]*Columbia University,* [5]*University of Western Ontario*

Wrist posture and force effects on finger control
Peter Keir[1], Stephen May[1] | [1]*McMaster University*

S.4. (Regency Ballroom B) ***Neuromodulatory Strategies for Improving Motor Control after CNS Damage***

Chairs: **Aiko K. Thompson**, *University of South Carolina*
Jonathan R. Wolpaw, *New York State Dept Health*

Novel neuromodulation strategies for Parkinson's disease
Robert Chen[1] | [1]*Toronto Western Hospital, University of Toronto*

Plasticity in the Corticospinal Pathway after Human Spinal Cord Injury
Monica Perez[1] | [1]*University of Miami*

Acute Intermittent Hypoxia Enhances Neuroplasticity In Incomplete Sci
William Rymer[1], Milap Sandhu[1], Arun Jayaraman[1] | [1]*Rehabilitation Institute of Chicago*

Changing a reflex to improve walking: operant conditioning of the soleus h-reflex in people with chronic incomplete spinal cord injury
Aiko Thompson[1] | [1]*Medical University of South Carolina*

Stimulation-induced plasticity in corticospinal transmission to motoneurones
Janet Taylor[1], Siobhan Donges[1], Jessica D'Amico[1] | [1]*Neuroscience Research Australia*

Using targeted neuroplasticity for rehabilitation
Jonathan Wolpaw[1] | [1]*Wadsworth Center (NY State Dept. of Health) and SUNY Albany*

S.5. (Regency Ballroom C) ***Joint ISEK-ISB symposium***

Chairs: **Karen Søgaard**, *University of Southern Denmark*

Glen Lichtwark, *University of Queensland*

Introduction

Catherine Disselhorst-Klug, *RWTH Aachen University*

Forearm muscle activity differs during gripping in people with tennis elbow compared to healthy individuals.

Nagarajan Manickaraj[1], Leanne M Bisset[2], Justin J Kavanagh[2] | [1]*PhD Student, Griffith University,* [2]*Griffith University*

An electromyographic evaluation of elastic band exercises targeting neck and shoulder pain

Thomas Grøndberg[1], Lars Kristensen[1], Ying Gao [2], Mike Murray[1], Gisela Sjøgaard[1], Karen Søgaard[1]

[1]*University of Southern Denmark,* [2]*University of Jyväskylä*

Factors affecting smoothness of head movements

Marit Thielemann[1], Nina Vøllestad[1] | [1]*University of Oslo*

The additional value of electromyography in system identification and parameter estimation to assess the contribution of underlying systems in standing balance

Jantsje Pasma[1], Joost van Kordelaar[2], Digna de Kam[3], Vivian Weerdesteyn[3], Alfred Schouten[1], Herman van der Kooij[2] | [1]*Delft University of Technology,* [2]*University of Twente,* [3]*Radboud University Medical Center*

Intrinsic foot muscle activity in response to different loading conditions

Andrew Cresswell[1], Glen Lichtwark[1], Luke Kelly[1] | [1]*The University of Queensland*

S.6. (Regency Ballroom D) ***Stepping out of the lab: EMG in daily life***

Chairs: **Kat M. Steele**, *University of Washington*

Andrew Sawers, *University of Illinois*

Fully-Integrated Stretchable Epidermal Electronics and Biosensors

Roozbeh Ghaffari[1] | [1]MC10 Inc.

A Wireless Surface EMG System for Daily Activity Measurement

Yi Su[1], Sudhamayee Routhu[1], **Kee Moon**[1], Yusuf Ozturk[1] | [1]*San Diego State University*

Tattoo-like, long-term electromyography sensors for quantifying muscle fatigue and recovery

Nanshu Lu[1], Luke Nicolini[1], Dragan Djurdjanovic[1] | [1]*University of Texas at Austin*

EMG-based Online Intent Recognition for a Powered Lower Limb Prosthesis

John Spanias[1], Eric Perreault[1], **Levi Hargrove**[2] | [1]*Northwestern University, Rehabilitation Institute of Chicago,* [2]*Rehabilitation Institute of Chicago, Northwestern University*

NeuroGame Therapy for the Improvement of Ankle Control in Children with Cerebral Palsy

Torey Gilbertson[1], Sarah McCoy[1], Kristie Bjornson[2], Robert Price[1], Chet Moritz[1]

[1]*University of Washington,* [2]*Seattle Children's Research Institute, University of Washington*

Backyard Brains: Using EMGs as an entry into neuroscience education

Gregory Gage[1] | [1]*Backyard Brains*

17:00 – 18:30 POSTER SESSION I & EXHIBITORS (CRYSTAL BALLROOM)

Sponsored by Northwestern University

Thursday, July 7

08:00 – 09:00 (*Regency Ballroom AB)*

KEYNOTE PRESENTATION

The Foot Core: A new paradigm
Irene Davis, *Harvard Medical School*
Chair: **Yasin Y Dhaher,** *Northwestern University*

09:00 – 09:30 **BREAK** (CRYSTAL BALLROOM)

09:30 – 11:00 **PARALLEL SESSIONS**

S.7. *(Regency Ballroom A)* ***Synchrony and frequency in neuromuscular control***
Chairs: **Francisco Valero-Cuevas**, *University of Southern California*
Christopher Laine, *University of Southern California*

Synchrony and frequency in neuromuscular control
Christopher Laine[1] | [1]*Univ of Southern California*

Motor control of upper airway dilator muscles
John Trinder[1] | [1]*University of Melbourne*

Investigating neural strategies for muscle coordination
Christopher Laine[1], **Francisco Valero-Cuevas[1]** | [1]*University of Southern California*

Investigating the neural substrate of motor coordination using muscle networks
Tjeerd Boonstra[1] | [1]*University of New South Wales*

Motor unit synchronization revisited: Estimating the proportion of common synaptic inputs to population of motor neurons in humans
Francesco Negro[1], Utku Şükrü Yavuz[1], Dario Farina[1] | [1]*Universitätsmedizin Göttingen*

Sensitivity of intermuscular coherence to identify common oscillatory synaptic inputs to motor neurons
Kevin Keenan[1], Francesco Negro[2], Dario Farina[2], Roger Enoka[3] | [1]*University of Wisconsin-Milwaukee,* [2]*Georg-August University ,* [3]*University of Colorado*

S.8. *(Regency Ballroom B)* ***Neuromuscular Electrical Stimulation: Time to Turn the Page***
Chairs: **Nicola Maffiuletti**, *Schulthess Clinic*
Marco Minetto, *University of Turin*

Maximising the central contribution to electrically-evoked contractions
David Collins[1], Matheus Wiest[1], Austin Bergquist[2] | [1]*University of Alberta,* [2]*University of Toronto*

Introduction and Conclusion to the symposium "Neuromuscular Electrical Stimulation: Time to Turn the Page"
Nicola Maffiuletti[1], **Marco Minetto[2]** | [1]*Schulthess Clinic,* [2]*University of Turin*

Predictors of response to neuromuscular electrical stimulation training
Marco Alessandro Minetto[1], Isabelle Vivodtzev[2], Giuseppe Massazza[1], **Nicola Maffiuletti[3]**
[1]*University of Turin,* [2]*Univ Grenoble Alpes and Inserm U 1042,* [3]*Schulthess Clinic*

Spatially Distributed Sequential Stimulation: Method to Reduce Muscle Fatigue During Transcutaneous Functional Electrical Stimulation

Kei Masani[1], Dimitry Sayenko[2], Robert Nguyen[3], Vishvek Babbar[4], Tomoyo Hirabayashi[5], Austin Berquist[4], **Milos Popovic[4]** | [1]*Toronto Rehab and University of Toronto,* [2]*University of California,* [3]*ETH Zurich,* [4]*University of Toronto and Toronto Rehab,* [5]*Toronto Rehab*

An Algorithm for NMES Therapy after Knee Surgery: A Novel Structured Approach

Jennifer Stevens-Lapsley[1], Andrew Kittelson[1], Yocheved Laufer[2], Michal Elboim-Gabyzon[2], Nicola Maffiuletti[3] | [1]*Universtiy of Colorado, Anschutz Medical Campus,* [2]*University of Haifa,* [3]*Shulthess Clinic*

Low-frequency pulsed currents vs. khz-frequency alternating currents

Marco Vaz[1] | [1]*Federal University Of Rio Grande Do Sul*

O.7. ***EMG: signal processing***

(Regency Ballroom C) **Chairs:** **Lucas J. McKay**, *Emory University*
Winnie Jensen, *Aalborg University*

O.7.1 Optimum threshold for slope sign changes and zero crossing features.

Asim Waris[1], Rosa Hugosdottir[1], Julie Gade[1], Kevin Englehart[2], Erik Scheme[2], Ernest Nlandu Kamavuako[1] | [1]*Aalborg University,* [2]*University of New Brunswick*

O.7.2 Variability of Features Extracted from sEMG Signal

Yiyang Shi[1], Dawn MacIsaac[1], Philip Parker[1] | [1]*University of New Brunswick*

O.7.3 Wavelet-based functional ANOVA to reveal statistically-significant contrasts between EMG waveforms recorded in different experimental conditions

J. Lucas McKay[1], Torrence Welch[1], Brani Vidakovic[1], Lena Ting[1] | [1]*Emory University and Georgia Tech*

O.7.4 Nonnegative matrix factorization to assess spatiotemporal muscle activation

Didier Staudenmann[1], Andreas Dafertshofer[2], Dick Stegeman[3], Jaap van Dieen[2]

[1]*University of Fribourg, Movement and Sport Science,* [2]*Vrije Universiteit Amsterdam,* [3]*Radboud University Medical Centre*

O.7.5 Analysis of amplitude estimation of non-stationary myoelectric signals

David Hofmann[1] | [1]*Emory University*

O.7.6 Automated Detection of Fasciculations in Motor Neurone Disease Patients using B mode Ultrasound: A Comparison with Electromyography.

Kate Bibbings[1], Peter Harding[1], Nick Combes[2], Ian Loram[1], Emma Hodson-Tole[1] | [1]*Manchester Metropolitan University,* [2]*Preston Royal Hospital*

O.8. *Motor performance and Ergonomics*
(Regency Ballroom D) Chairs: **Peter Keir**, *McMaster University*
Usha Kuruganti, *University of New Brunswick*

O.8.1 The surgeon's workload; traditional laparoscopic (TLS) versus robot-assisted (RAS) surgery

Bente Rona Jensen[1], Morten Dedenroth[1], Dorte Hartwell[1], Berit Mosgaard[1], Annemette Jørgensen[2], Torur Dalsgaard[1] | [1]*University of Copenhagen,* [2]*Aalborg University Hospital*

O.8.2 Characterizing changes in neuromuscular control in response to different locomotor tasks using electromyographic wavelet analysis

Linard Filli[1], Martina Waser[1], Christopher Easthope[2], Tim Killeen[2], Christian Meyer[1], Lilla Loerincz[1], Armin Curt[2], Marc Bolliger[2], Bjoern Zoerner[1] | [1]*University Hospital Zurich,* [2]*Balgrist University Hospital*

O.8.3 Temporal trunk muscle patterns are altered ipsilateral to back injury side despite perception of recovery

D Adam Quirk[1], Cheryl Hubley-Kozey[1] | [1]*Dalhousie University*

O.8.4 Adapting to different running footwear: A neuromuscular approach

Devon Coetzee[1], Nicholas Tam[1], Ross Tucker[2], **Yumna Albertus**[1] | [1]*University of Cape Town ,* [2]*University of Free State*

O.8.5 Surface electromyographic inter-individual variability and pattern recognition in front crawl swimming

Jonas Martens[1], Daniel Daly[1], Kevin Deschamps[1], Filip Staes[1], Ricardo Fernandes[2] | [1]*KU Leuven,* [2]*University of Porto*

O.8.6 Posture variation and maximal acceptable work pace during repetitive work

Tessy Luger[1], Svend Erik Mathiassen[2], Tim Bosch[3], Marco Hoozemans[1], Marjolein Douwes[3], DirkJan Veeger[1], Michiel de Looze[1] | [1]*Vrije Universiteit Amsterdam,* [2]*University of Gävle,* [3]*TNO*

11:00 – 12:30 PARALLEL SESSIONS

O.9. *EMG: novel applications*
(Regency Ballroom A) Chairs: **Joshua Kline**, *Delsys Inc.*
Jon Shemmel, *University of Otago*

O.9.1 Changes in the surface electromyographic signal during high intensity fatiguing dynamic exercise

Clare Davidson[1], Giuseppe De Vito[1], Madeleine Lowery[1] | [1]*University College Dublin*

O.9.2 Feasibility of uterine electromyography outside pregnancy

Chiara Rabotti[1], Federica Sammali[1], Nienke Kuijsters[2], Benedictus Schoot[3], Massimo Mischi[1]
[1]*Eindhoven University of Technology,* [2]*Catharina Hospital,* [3]*University Hospital Gent*

O.9.3 Nonlinear Analysis of Electromyography in Parkinson's Disease During Isometric Leg Extension

Matthew Flood[1], Bente Jensen[2], Anne Malling[3], Martin Rose[3], Madeleine Lowery[1]
[1]*University College Dublin,* [2]*University of Copenhagen,* [3]*University of Copenhagen*

O.9.4 Chronic EMG activity reveals early changes in muscle activation in treadmill running SOD1 mice

Katharina Quinlan[1], CJ Heckman[1], Matthew Tresch[1], Vicki Tysseling[1] | [1]*Northwestern University Feinberg School of Medicine*

O.9.5 The gluteus medius, gluteus minimus and tensor fascia latae are more active during gait in post-menopausal women with greater trochanteric pain syndrome

Charlotte Ganderton[1], **Tania Pizzari[1]**, Adam Semciw[2] | [1]*La Trobe University,* [2]*University of Queensland*

O.9.6 Quadratus femoris is minimally active in common rehabilitation exercises

Adam Semciw[1], Jodie McClelland[2], Damien Moore[2], Tania Pizzari[2] | [1]*The University of Queensland,* [2]*La Trobe University*

O.10. ***Sensorimotor control and learning***

(Regency Ballroom B) **Chairs: Keith Gordon**, *Northwestern University*

José Luis Pons, *Cajal Institute CSIC*

O.10.1 Locomotor Adaptation to Stable and Unstable Environments

Keith Gordon[1], Mengnan Wu[1], Geoffery Brown[1] | [1]*Northwestern University*

O.10.2 Hybrid Robotic System for Reaching Rehabilitation after Stroke

Francisco Resquin[1], Jose Gonzalez-Vargas[1], Jaime Ibañez[1], Fernando Brunetti[2], Iris Dimbwadyo[3], Susana Alves[4], Laura Carrasco[3], Laura Torres[3], **José Luis Pons[1]** | [1]*Spanish National Research Council,* [2]*Catholic University Nuestra Señora de la Asunción,* [3]*La Salle,* [4]*Centro de Referencia Estatal de Atención al Daño Cerebral*

O.10.3 Size of kinematic error affects retention of locomotor adaptation in children with cerebral palsy

Rongnian Tang[1], Janis Kim[1], Deborah J Gaebler-Spira[1], Ming Wu[1] | [1]*Rehabilitation Institute Of Chicago*

O.10.4 Motor learning with pain results in long-lasting changes in motor strategies

Sauro Salomoni[1], Welber Marinovic[1], Timothy Carroll[1], **Paul Hodges[1]** | [1]*The University of Queensland*

O.10.5 Neck pain: Do head movement qualities change during an intensive treatment period?

Marit Thielemann[1], Nina Vøllestad[1] | [1]*University of Oslo*

O.10.6 Multichannel SEMG activity and force variability during isometric contractions at low level forces in diabetic individuals

Eneida Y Suda[1], Isabel CN Sacco[1], Thiago T Kawamura[1], Rogerio P Hirata[2], Afshin Samani[2], Pascal Madeleine[2] | [1]*University of São Paulo,* [2]*Aalborg University*

O.11. ***Novel measurement techniques***
(Regency Ballroom C) Chairs: **Oliver Kannape**, *University of Central Lancashire*
Chris Thompson, *Temple University*

O.11.1 High density multi-channel needle electromyography: towards electrical cross-sectional imaging of human skeletal muscle
Bashar Sheikh Hasan[1], Enrique Escobedo-Cousin[1], Hock Soon Low[1], Anthony O'Neill[1], Stuart Baker[1], **Roger Whittaker[1]** | [1]*Newcastle University*

O.11.2 Spatiotemporal muscle activation of a sustained contraction until task failure assessed with nonnegative matrix factorization
Didier Staudenmann[1], Andreas Daffertshofer[2], Dick Stegeman[3], Roger Enoka[4]
[1]*University of Fribourg, Movement and Sport Science,* [2]*Move Research Institute / Vrije Universiteit Amsterdam,* [3]*Donders Institute / Radboud University Medical Centre,* [4]*Department of Integrative Physiology / University of Colorado*

O.11.3 Monitoring changes in motor unit behavior following short-term high intensity interval training with high-density surface electromyography motor unit tracking
Eduardo Martinez-Valdes[1], Deborah Falla[2], Francesco Negro[2], Frank Mayer[1], Dario Farina[2]
[1]*University of Potsdam, Potsdam, Germany,* [2]*University Medical Center Göttingen, Georg-August University, Göttingen, Germany*

O.11.4 Neuromuscular control adaptations in strength trained athletes: a high-density EMG study
Alessandro Del Vecchio[1], Federico Quinzi[1], Ilenia Bazzucchi[1], Luigi DI Luigi[1], Francesco Felici[1]
[1]*University of Rome "Foro Italico"*

O.11.5 Assessing somatosensory evoked potentials using high density surface electromyography grids
Tessy Luger[1], Andreas Daffertshofer[1] | [1]*Vrije Universiteit Amsterdam*

O.11.6 Design of New Multi-channel Electrodes for the Collection of Surface Electromyography Monopolar Signals for the Software Generation Signals for Linear Array and Laplacian Configurations for Digital Signal Processing
Jeff Kilby[1], Krishnamachar Prasad[1], Grant Mawston[1] | [1]*Auckland University of Technology*

O.12. ***Motor Units II***
(Regency Ballroom D) Chairs: **Nina Suresh**, *Northwestern University*
Kevin McGill, *VA Palo Alto Health Care System*

O.12.1 Comparison of Five Methods for Estimating Motor Unit Firing Rates from Firing Times
Lukai Liu[1], Paolo Bonato[2], **Edward Clancy[1]** | [1]*Worcester Polytechnic Institute,* [2]*Spaulding Rehabilitation Hospital & Harvard Medical School*

O.12.2 The common synaptic input signal underlying the common drive
Kevin McGill[1], Zoia Lateva[1], M. Elise Johanson[1] | [1]*VA Palo Alto Health Care System*

O.12.3 Assessment of single motor unit activation in central and peripheral neuronal disorders
Kathrin Koch[1], Catherine Disselhorst-Klug[1] | [1]*RWTH Aachen University*

O.12.4 Modulation of motor units serving different VM fibers during knee extension
Hélio Cabral[1], Leonardo de Souza[1], Roger Mello[2], Liliam Oliveira[1], Taian Vieira[1] | [1]*Universidade Federal do Rio de Janeiro,* [2]*Escola Naval/Marinha do Brasil*

O.12.5 Initial estimates of motoneuron after-hyperpolarization through the tonic discharge of motor unit populations

Iva Stojkovska[1], Michael Johnson[1], Francesco Negro[2], Matthieu Chardon[1], Dario Farina[2], Charles Heckman[1], Chris Thompson[3] | [1]*Northwestern University,* [2]*University Medical Center, Georg-August University,* [3]*Temple University*

O.12.6 The Temporal Structure of Intermuscular Motor Unit Synchronization: Application of Wavelet Coherence

Maurice Mohr[1], Vinzenz von Tscharner[1], Benno Nigg[1] | [1]*University of Calgary*

12:30 – 13:30	**LUNCH, POSTERS & EXHIBITORS** (CRYSTAL BALLROOM)
13:30 – 14:30 (*Regency Ballroom AB)*	**KEYNOTE PRESENTATION** ***Clinical Applications for advanced electromyographic techniques: A field in transition*** **W. Zev Rymer**, *Rehabilitation Institute of Chicago (RIC)* Chair: **Carlo de Luca**, *Delsys Inc.*
14:30 – 15:00	**BREAK** (CRYSTAL BALLROOM)
15:00 – 16:30	**PARALLEL SESSIONS**

S.9. *(Regency Ballroom A)* ***Implementation of Impairment Based Neuro-Rehabilitation Devices and Technologies following Brain Injury***

Chairs: **Julius Dewald**, *Northwestern University*

Michael Ellis, *Northwestern University*

The use of haptic robots to study neural mechanisms underlying the expression of sensorimotor impairments in stroke.

Julius Dewald[1], Albert Chen[2], Jun Yao[1] | [1]*Northwestern University Feinberg School of Medicine,* [2]*Athenahealth*

Robotic assessment of the "good arm" following stroke

Sean Dukelow[1], Jennifer Semrau[1], Troy Herter[2], Stephen Scott[3] | [1]*Hotchkiss Brain Institute/ University of Calgary,* [2]*University of South Carolina,* [3]*Queen's University*

Robotic Measurement and Intervention for Synergy-Related Reaching Dysfunction Following Stroke

Michael Ellis[1], Julius Dewald[1] | [1]*Northwestern University*

Using Robotic Systems to Assess Proprioceptive Deficits in Individuals with Hemiparetic Stroke

Netta Gurari[1] | [1]*Northwestern University*

Training modalities in robot-mediated upper limb rehabilitation in stroke

Arno Stienen[1] | [1]*University of Twente*

4D EEG: Assessing the role of the sensorimotor cortex in reflex modulation during motor control.

Frans van der Helm[1], Yuan Yang[1], T Solis-Escalante[1], M Vlaar[1], Jun Yao[2], Jules Dewald[2], Alfred Schouten[1] | [1]*Delft University of Technology,* [2]*NOrthwestern University*

S.10. (Regency Ballroom B) ***Neural mechanisms underlying falls and impaired balance: an introspective from animal to patient***

Chairs: **Claire Honeycutt**, *Arizona State University*

Jacques Duysens, *Katholieke Universiteit Leuven*

Are hypermetric stretch reflexes significant contributors to falls in stroke survivors?

Claire Honeycutt[1], Mark Grabiner[2] | [1]*Arizona State University,* [2]*University of Illinois at Chicago*

Strategies to maintain static and dynamic lateral stability during locomotion in the cat

Boris Prilutsky[1], Hangue Park[1], Ricky Mehta[1], Joshua Jarrell[1], Stephen DeWeerth[1], Bradley Farrell[2]

[1]*Georgia Institute of Technology,* [2]*Georgia State University*

New rehabilitation tools and technologies to improve balance and mobility

Joyce Fung[1] | [1]*McGill University*

Balance reactions following perturbations to touch are more pronounced when standing on an unstable surface

John Misiaszek[1], Jesse Vander Meulen[1] | [1]*University of Alberta*

Basic insights in tripping responses can assist in designing appropriate fall prevention programs.

Jacques Duysens[1], Zrinka Potocanac[2] | [1]*Katholieke Universiteit Leuven,* [2]*Jozef Stefan Institute*

Altered sensorimotor transformations for balance in Parkinson's disease

J. Lucas McKay[1], Madeleine Hackney[2], Lena Ting[1] | [1]*Emory University and Georgia Tech,* [2]*Emory University and Atlanta VAMC*

S.11. (Regency Ballroom C) ***EMG Signal Analysis in Clinical Applications***

Chairs: **Madeleine Lowery**, *University College Dublin*

Edward (Ted) Clancy, *Worcester Polytechnic Institute*

The use of EMG in neuromuscular diagnosis: an overview

Dick Stegeman[1] | [1]*Radboud University Medical Centre*

A novel method for analysis of pathological tremor in electroencephalograms

Ales Holobar[1], Juan Gallego[2], Rok Istenic[1], Eduardo Rocon[2], Juan Romero[3], Julian Benito-Leon[4], José Pons[5], Vojko Glaser[1] | [1]*University of Maribor,* [2] *Spanish National Research Council,* [3]*School of Biomedical Sciences, Universidad Francisco de Vitoria,* [4]*University Hospital "12 de Octubre", Madrid, Spain,* [5]*Cajal Institute, Spanish National Research Council*

High Density Surface EMG Examination of Motor Unit Firing Behavior in Amyotrophic Lateral Sclerosis

Faezeh Jahanmiri-Nezhad[1], Ales Holobar[2], William Rymer[3], **Ping Zhou**[4] | [1]*University of Northern Iowa,* [2]*University of Maribor,* [3]*Rehabilitation Institute of Chicago,* [4]*University of Texas Health Science Center at Houston*

A novel device for assessing pelvic floor muscle function in women

Stéphanie Madill[1], Angelica Lang[1], Gordon Sarty[1] | [1]*University of Saskatchewan*

Alterations in motor unit firing rate and action potential properties during isometric fatigue in stroke survivors

Lara McManus[1], Xiaogang Hu[2], William Rymer[3], Madeleine Lowery[1], Nina Suresh[4]

[1]University College Dublin, [2]University of North Carolina-Chapel Hill and North Carolina State University, [3]Rehabilitation Institute of Chicago and Northwestern University, [4]Rehabilitation Institute of Chicago

Contribution of deep and superficial motor units to the surface EMG of the masseter muscle.
Johannes van Dijk[1], Ulrike Eiglsperger[1], Johanna Radeke[1], Hans Schindler[2], **Bernd Lapatki[1]**
[1]University of Ulm, [2]University of Heidelberg

S.12. *(Regency Ballroom D)* ***Spastic muscle and its treatment using botulinum toxin: new viewpoints with major implications***
Chairs: **Can A. Yucesoy**, *Boğaziçi University*
Richard Lieber, *Rehabilitation Institute of Chicago*

Experimental and Modeling Assessments Specific to Treatment Aims Indicate New Viewpoints and an Understanding of Mechanisms of Effects of Botulinum Toxin Type A
Can Yucesoy[1], Filiz Ates[2] | *[1]Bogazici University, [2]Waseda University*

Structural and Functional Consequences of Neurotoxin injection in a Rat Model System
Richard Lieber[1], Samuel Ward[2] | *[1]Northwestern University, [2]University of California, San Diego*

The effect of botulinum toxin injections on gastrocnemius muscle volume in children with spastic cerebral palsy
Adam Shortland[1] | *[1]Guy's & St Thomas' Foundation Trust*

Muscle material properties in children with hemiplegic cerebral palsy
Sabrina Lee[1], Deborah Gaebler-Spira[1], Li-Qun Zhang[1], William Rymer[2], Katherine Steele[3]
[1]Northwestern University, [2]Rehabilitation Institute of Chicago, [3]University of Washington

Persistent muscle weakness and contractile material loss in a clinically relevant botulinum toxin type-a (btx-a) injection protocol
Rafael Fortuna[1], Andrew Sawatsky[1], Walter Herzog[1] | *[1]University of Calgary*

Intraoperative Testing of Individual Spastic Knee Flexor Muscles' Capacity to Affect Impeded Knee Joint Function in Cerebral Palsy Patients
Filiz Ates[1], Yener Temelli[2], Can Yucesoy[3] | *[1]Waseda University, [2]Istanbul University, [3]Bogazici University*

16:30 – 18:00 **POSTER SESSION II & EXHIBITORS** (CRYSTAL BALLROOM)
Sponsored by Noraxon

19:30 – 23:00 **CONFERENCE BANQUET**
The Mid America Club
200 East Randolph Drive,
80th Floor, Aon Center,
Chicago, IL 60601

Friday, July 8

08:00 – 09:30 **PARALLEL SESSIONS**

S.13. *(Regency Ballroom A)* ***Prosthetics to Orthotics: Transferable Expertise***
Chairs: **Kostas Nizamis**, *University of Twente*
Arno Stienen, *University of Twente*

The state-of-the-art EMG control in dynamic orthoses
Derek Kamper[1] | [1]*Illinois Institute of Technology*

Unassisted FES is all you need to regain hand function
Thierry Keller[1] | [1]*Tecnalia Research and Innovation*

Direct mechanical control outperforms EMG control
Dick Plettenburg[1] | [1]*Delft University of Technology*

Surface EMG control in neurorehabilitation: experiences from EMG-driven modelling and robotic for upper and lower limb post-stroke rehabilitation
Dario Farina[1], Massimo Sartori[1], Andrea Turolla[2] | [1]*University Medical Center Goettingen,* [2]*IRCCS San Camillo Hospital Foundation*

The case for impedance control in wearable robotics
Elliott Rouse[1] | [1]*RIC / Northwestern University*

Structured panel discussion on prosthetics to orthotics: transferrable expertise
Arno Stienen[1] | [1]*University of Twente*

S.14. *(Regency Ballroom B)* ***Clinical applications of muscle synergies***
Chairs: **Kat M. Steele**, *University of Washington*
Jessica Allen, *Georgia Tech*

Function and dysfunction in brain connectivity coordinating muscle synergies in humans
Jason Kutch[1] | [1]*University of Southern California*

Does modularity in post-stroke motor coordination differ in dynamic and static tasks?
Jinsook Roh[1], Kevin Wilger[1], William Rymer[2], Randall Beer[3] | [1]*Temple University,* [2]*Northwestern University,* [3]*Rehabilitation Institute of Chicago*

Neuromotor modules as markers of diseased states and progress of motor recovery
Vincent C. K. Cheung[1], Giacomo Severini[2], Paolo Bonato[3], Andrea Turolla[4], Roy T. H. Cheung[5]
[1]*The Chinese University of Hong Kong,* [2]*University College Dublin,* [3]*Harvard Medical School,* [4]*IRCCS San Camillo Hospital,* [5]*The Hong Kong Polytechnic University*

Synergistic changes in muscle coordination post-stroke in a locomotor learning task
Gelsy Torres-Oviedo[1], Pablo Iturralde[1] | [1]*University of Pittsburgh*

Do muscle synergies change after treatments in cerebral palsy?
Benjamin Shuman[1], Marije Goudriaan[2], Kaat Desloovere[1], Michael Schwartz[3], Katherine Steele[1]
[1]*University of Washington,* [2]*KU Leuven,* [3]*Gillette Children's Specialty Healthcare*

Long-term training modifies the modular structure and organization of walking balance control
Andrew Sawers[1], Jessica Allen[2], Lena Ting[2] | [1]*University of Illinois at Chicago,* [2]*Emory University*

O.13. *Muscle Physiology*
(Regency Ballroom C) Chairs: **Rick Leiber**, *Rehabilitation Institute of Chicago*
Tom Sandercock, *Northwestern University*

O.13.1 Passive stiffness of lumbar multifidus and erector spinae muscle fibres is decreased in ENT1 deficient mice

Kelsey Gsell[1], Derek Zwambag[1], Cheryle Séguin[2], Stephen Brown[1] | [1]*University of Guelph,* [2]*Western University*

O.13.2 High-resolution in vivo measurement of changes in architecture of the human medial gastrocnemius muscle during passive lengthening

Bart Bolsterlee[1], Arkiev D'Souza[1], Simon Gandevia[1], Robert Herbert[1] | [1]*Neuroscience Research Australia (NeuRA)*

O.13.3 Inhomogeneity of emg-and ultrasound-detected onset of voluntary muscle activation explains their inconsistent relationship

Angela Dieterich[1], Alberto Botter[2], Taian Vieira[2], Anneli Peolsson[3], Frank Petzke[1], Paul Davey[4], Deborah Falla[1] | [1]*University Medical Center Goettingen,* [2]*Politecnico di Torino,* [3]*Linköping University,* [4]*Curtin University*

O.13.4 Feasibility of quantitative uterine motion analysis by ultrasound speckle tracking outside pregnancy

Federica Sammali[1], Nienke Kuijsters[2], Chiara Rabotti[1], Benedictus Schoot[3], Massimo Mischi[1]
[1]*Eindhoven University of Technology,* [2]*Catharina Hospital,* [3]*University Hospital Ghent*

O.13.5. Three different cell types produce collagen during skeletal muscle fibrosis

Richard Lieber[1] Mark Chapman[2] | [1]*Northwestern University,* [2]*University of California, San Diego*

O.13.6 Functional Relevance of Epimuscular Interactions at Forearm: In vivo Assessments with Ultrasound Elastography

Filiz Ates[1], Yasuo Kawakami[1] | [1]*Waseda University*

O.14. *Movement Disorders*
(Regency Ballroom D) Chairs: **Monica Perez**, *University of Miami*
Winfred Mugge, *Delft University of Technology*

O.14.1 A startling acoustic stimulus influences initial and late phases of postural responses differently in people after stroke

Jolanda Roelofs[1], Milou Coppens[1], Nicole Donkers[1], Jorik Nonnekes[1], Vivian Weerdesteyn[1], Alexander Geurts[1] | [1]*Radboud university medical center*

O.14.2 Evaluations of wrist spasticity post stroke

Sang Hoon Kang[1], Song Joo Lee[2], Li-Qun Zhang[3] | [1]*Northwestern University; Rehab. Inst. of Chicago; UNIST,* [2]*Northwestern University; Rehab. Inst. of Chicago; KIST,* [3]*Northwestern University; Rehab. Inst. of Chicago; Northshore University HealthSystem*

O.14.3 Coordination of deep hip muscle activity is altered in symptomatic femoroacetabular impingement

Laura Diamond[1], Wolbert Van den Hoorn[2], Kim Bennell[1], Tim Wrigley[1], Rana Hinman[1], John O'Donnell[3], Paul Hodges[2] | [1]*The University of Melbourne,* [2]*The University of Queensland,* [3]*St Vincent's Hospital*

O.14.4 Trunk neuromuscular patterns in recovered low back injury individuals differs between those who do and do not reinjure at one-year follow up

Cheryl Hubley-Kozey[1], **D Adam Quirk[1]**, Daniel Trudel[2] | [1]*Dalhousie University,* [2]*Canadian Armed Forces*

O.14.5 Extrinsic finger muscle stiffness contributes substantially to increased passive stiffness of the wrist and finger joints in chronic hemiparetic stroke individuals: A Pilot Study

Benjamin Binder-Markey[1], Julius Dewald[1], Wendy Murray[1] | [1]*Northwestern University*

O.14.6 Humeral rotational capabilities of stroke survivors and pattern recognition of intent during shoulder tasks

Joseph Kopke[1], Levi Hargrove[2], Michael Ellis[1] | [1]*Northwestern University,* [2]*Northwestern University; Rehabilitation Institute of Chicago*

09:30 – 10:00	**BREAK** (CRYSTAL BALLROOM)
10:00 – 11:00 (*Regency Ballroom AB)*	**KEYNOTE PRESENTATION** ***Feeling the force: DARPA's HAPTIX program to create prosthetic hands that restore touch sensations and proprioception*** **Doug Weber**, University of Pittsburgh **Chair: Levi Hargrove**, *Northwestern University*
11:00 – 12:00 (*Regency Ballroom AB)*	**GENERAL ASSEMBLY**
12:00 – 13:30	**LUNCH, POSTER SESSION III & EXHIBITORS** (CRYSTAL BALLROOM)
13:30 – 15:00	**PARALLEL SESSIONS**

S.15. ***Multichannel EMG: decomposition and other applications***

(Regency Ballroom A) **Chairs: Dario Farina**, *University Medical Center Göttingen*
Ales Holobar, *University of Maribor*

Convolutive source deflation significantly improves convergence of blind motor unit identification from surface electromyograms

Uros Manacinski[1], Ales Holobar[1] | [1]*University of Maribor, Faculty of Electrical Engineering and Computer Science*

High-density surface electromyograms: do they sample representative muscle active?

Taian Vieira[1] | [1]*Politecnico di Torino*

Topographical characteristics of motor units of the complete facial musculature determined by means of high-density surface EMG.

Bernd Lapatki[1], Alisa Barth[1], Johannes Neubert[1], Johanna Radeke[1], Dick Stegeman[2], Ales Holobar[3], Johannes van Dijk[1] | [1]*University of Ulm,* [2]*Radboud University Medical Centre,* [3]*University of Maribor*

Longitudinal tracking of individual motor units using high-density surface electromyography

Francesco Negro[1], Eduardo Martinez-Valdes[2], Christopher Thompson[3], Michael Johnson[4], Deborah Falla[1], Charles Heckman[4], Dario Farina[1] | [1]*Universitätsmedizin Göttingen,* [2]*University of Potsdam,* [3]*Temple University,* [4]*Northwestern University*

Differences in motor unit discharge characteristics among proximal and distal muscles of the upper limb in individuals with chronic hemiparetic stroke

Laura Miller McPherson[1], Francesco Negro[2], Chris Thompson[3], CJ Heckman[4], Dario Farina[2], Jules Dewald[4] | [1]*Florida International University,* [2]*University of Gottingen,* [3]*Temple University,* [4]*Northwestern University*

How synaptic organization shapes the motoneuron to EMG transform

CJ Heckman[1], Randy Powers[2] | [1]*Northwestern University,* [2]*University of Washington*

S.16. (Regency Ballroom B) ***Mobilizing Data: Research at the Intersection of Data Science and Biomechanics***

Chairs: **Jennifer Hicks**, *Stanford University*

Scott Delp, *Stanford University*

The Mobilize Center: accelerating movement science with big data

Jennifer L. Hicks[1] , Joy P. Ku[1] , Scott L. Delp[1,2] | [1]*Departments of Bioengineering and* [2]*Mechanical Engineering, Stanford University*

Stepping forward? Patient-specific measures of altered control to improve treatment outcomes in cerebral palsy

Katherine Steele[1], Michael Schwartz[2] | [1]*University of Washington,* [2]*Gillette Children's Specialty Healthcare*

Detecting foot strike from kinematics, a case study in the debate between hypothesis-first and data-first methods

Sean Osis[1], Reed Ferber[1] | [1]*University of Calgary*

Characterizing Clinically Meaningful Phenotypes of Osteoarthritis Progression: Eight-Year Data from the Osteoarthritis Initiative

Eni Halilaj[1], Jason Fries[1], Jennifer Hicks[1], Scott Delp[1] | [1]*Stanford University*

Data and data management for finite element analysis in joint biomechanics

Ahmet Erdemir[1] | [1]*Cleveland Clinic*

Moving Forward: From Physical Activity Monitoring to Physical Performance Monitoring

Matthew Smuck[1] | [1]*Stanford University*

S.17. (Regency Ballroom C) ***Practical Application of Electrophysiology and Kinesiology***

Chairs: **Tohru Kiryu**, *Niigata University*

Masaki Yoshida, *Osaka Electro-Communication University*

Application of multi-channel surface EMG technique to researches of aging and lifestyle-related diseases

Kohei Watanabe[1] | [1]*Chukyo University*

Rehabilitation robot using muscle activity and neural decoding

Toshihiro Kawase[1], Duk Shin[1], Hiroyuki Kambara[1], Natsue Yoshimura[1], Yasuharu Koike[1] | [1]*Tokyo Institute of Technology*

Ubiquitous approach for health and sport

Masaki Yoshida[1], Zunyi Tang[1], Masaki Sekine[1], Toshiyo Tamura[1] | [1]*Osaka Electro-Communication University*

A Remote and Non-Contact Monitoring System of Physiological Indices to Cope with Visually Induced Motion Sickness

Makoto Yoshizawa[1], Norihiro Sugita[1], Makoto Abe[2], Akira Tanaka[3], Noriyasu Homma[1], Tomoyuki Yambe[1] | [1]*Tohoku University,* [2]*Shinshu University,* [3]*Fukushima University*

Brain-muscle-machine interface: controlling a prosthetic hand

Ryu Kato[1] | [1]*Yokohama National University*

S.18. ***Intermittent control***
(Regency Ballroom D) Chairs: **Ian Loram**, *Manchester Metropolitan University*
Scott Beardsley, *Marquette University*

Intermittent Control provides a deterministic explanation of linear and remnant components of human stance control without injection of random noise.
Cornelis van de Kamp[1], Henrik Gollee[2], Peter J Gawthrop[3], Ian D Loram[4] | [1]*Delft University of Technology,* [2]*University of Glasgow,* [3]*University of Melbourne,* [4]*Manchester Metropolitan University*

Intermittent control: a general paradigm for understanding sensorimotor control
Ian Loram[1], Peter Gawthrop[2], Henrik Gollee[3] | [1]*Manchester Metropolitan University,* [2]*The University of Melbourne, ,* [3]*University of Glasgow,*

A machine learning model of intermittent control
Ryan Cunningham[1], Ian Loram[1] | [1]*Manchester Metropolitan University*

Remnant response in visual-manual tasks and intermittent control
Henrik Gollee[1], Ian Loram[2], Peter Gawthrop[3] | [1]*University of Glasgow,* [2]*Manchester Metropolitan University,* [3]*University of Melbourne*

Sensorimotor dynamics in the brain during intermittent control of goal-directed movements
Scott Beardsley[1], Robert Scheidt[1] | [1]*Marquette University*

A dual Kalman filter approach to adaptation in intermittent control
Jose Alvarez Martin[1], Henrik Gollee[1], Ian Loram[2], Peter Gawthrop[3] | [1]*University of Glasgow,* [2]*Manchester Metropolitan University,* [3]*University of Melbourne*

Intermittency using boundary control
James Patton[1], Amit Shah[1] | [1]*University of Illinois at Chicago (UIC), and the Rehabilitation Institute of Chicago (RIC)*

15:00 – 15:30	**BREAK** (REGENCY BALLROOM FOYER)
15:30 – 16:30 (*Regency Ballroom AB)*	**KEYNOTE PRESENTATION** Sponsored by **ISB** ***Optimizing Human Performance*** **Scott Delp**, Stanford University Chair: **Wendy Murray**, *Northwestern University*
16:30 – 17:00 (*Regency Ballroom AB)*	**AWARDS**
17:00 – 18:00 *Regency Ballroom Foyer*	**CLOSING RECEPTION** Sponsored by **ISB**

International Society of Biomechanics

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WEDNESDAY, JULY 6

08:30 – 09:30 **John Rogers**, University of Illinois

Epidermal Electronics for Electrophysiological Kinesiology

The skin is soft, curvilinear and time dynamic; modern electronics technology is not. Materials and devices that eliminate this profound mismatch in properties enable the deployment of new monitoring and stimulation systems that integrate intimately and non-invasively with the epidermis to provide continuous, clinical-quality EMG data, and many other parameters (accelerometry, motion, temperature, mechanical strain, pressure, hydration, etc) of interest in rehabilitation, prosthetics, movement disorders, sensorimotor control and muscle physiology. Recent work establishes a complete set of materials, mechanics designs and manufacturing approaches that enable these capabilities in a class of electronics with performance comparable to that of conventional wafer-based technologies. This talk will describe the foundational ideas for this type of 'epidermal' electronics platform, with examples in studies of prosthetics control and ergonomics, movement characteristics in Parkinson's patients, and behaviors in obstructive sleep apnea.

14:00 – 15:00 **Birgit Juul-Kristensen**, University of Southern Denmark

Why is it important to use EMG in Clinical research of musculoskeletal disorders?

Surface Electromyography (EMG) in clinical research of musculoskeletal disorders is an important technology challenging both developers and users.

EMG measurements may be useful in all phases of clinical research, including **1)** before patient treatment, **2)** during/in the early planning of patient treatment, and **3)** after treatment as an effect measure. In addition, EMG may be important in identifying new neuromuscular abnormalities of musculoskeletal conditions for planning **4)** surveillance and injury prevention strategies.

1) Before treatment it is important to verify patient muscle dysfunction compared with healthy controls (e.g. the aims of studying which muscles are overactive/too little active, as contributors for pain). Perspectives of such results are basis for developing targeted training programs for restoring potential muscle imbalance.

2) In the early planning of new training concepts the feasibility should be tested, as for example studying the ability for patients of using visual biofeedback guided training to selectively activate specific shoulder muscles/muscle parts. The perspectives are the possibility for testing effectiveness of such guidance, in e.g. restoring muscle imbalance and decrease pain in randomized controlled trials.

3) After treatment, when studying the direct effect of neuromuscular control training, e.g. in the neck, the activity of those muscles thought to be contributors to neck pain, and therefore also highly targeted in the training program, is very useful.

4) The musculoskeletal condition of joint hypermobility (JH) is an intrinsic risk factor for injuries, but effective prevention strategies require specifically information of whether and how an abnormal muscle activation strategy in this group is present.

THURSDAY, JULY 7

08:00 – 09:00 **Irene Davis**, Harvard Medical School

The Foot Core – A New Paradigm

The role of lumbo-pelvic-hip core stability in lower extremity motion has received much recent attention. The lumbo-pelvic-hip core consists of local stabilizers with small cross-sectional areas and small moment arms, which act to increase joint stability. These muscles provide a stable base such that the primary movers, muscles with larger cross-sectional areas and moment arms, can properly function. When core muscles are weak or are not recruited appropriately, the foundation becomes unstable and malaligned, and abnormal movement patterns of the trunk and lower extremity ensue. This can lead to a variety of lower extremity injuries.

We have proposed that the concept of core stability may be extended to the arch of the foot. The arch is also controlled with local stabilizers and global movers of the foot. The local stabilizers are the four layers of plantar intrinsic muscles. These muscles have small moment arms, small cross-sectional areas, and serve primarily to stabilize the arch. The global movers are the extrinsic muscles which have larger cross sectional areas, and larger moment arms. With each footstep, the intrinsic muscles act to control the degree and velocity of arch deformation. When they are not functioning properly, the foundation becomes unstable and malaligned, resulting in abnormal foot motion, increasing the risk of foot injuries.

The purpose of this presentation is to describe this new paradigm for viewing foot function, assessment, and treatment. It is hoped this will also raise awareness of the amazing function of our feet & their underappreciated potential for adaptation.

13:30 – 14:30 **W. Zev Rymer**, Rehabilitation Institute of Chicago

Clinical Applications For Advanced Electromyographic Techniques: A Field In Transition

The introduction of novel EMG instrumentation and advanced software algorithms has profoundly altered our ability to understand and quantify neurologic disorders. Many of these applications rely on multi-electrode recordings set up as EMG grids, with available designs allowing simultaneous recordings using up to 256 - 512 electrodes.

To illustrate, monopolar grid recordings allow us to map the spatial distribution of muscle activation over the whole muscle surface. We see substantial differences in spatial activation patterns within a muscle in neurological disorders such as stroke. We can also examine changes in muscle architecture by quantifying the spacing of EMG activity within the surface EMG maps.

Single differential recordings can help identify innervation/reinnervation zones in neurologic disorders such as ALS, producing a snapshot of the whole motoneuron pool in a comprehensive and noninvasive manner.

An additional valuable feature is the ability to decompose the recruitment and discharge rates of many motoneurons simultaneously. The availability of high density array EMG recordings has allowed us to assess changes in recruitment and firing rate properties of many motoneurons in the pool. In a small muscle such as the first dorsal interosseus (FDI), it is possible to map the discharge of virtually all of the motoneurons within the pool during isometric contractions.

Using these techniques, we have learned that there are systematic disruptions in recruitment and firing rate profiles of motor units that may promote an increase in motor deficits following stroke-related damage to corticospinal projections, or following white matter damage in traumatic spinal cord injury.

FRIDAY, JULY 8

10:00 – 11:00 **Doug Weber**, Defense Advanced Research Project Agency (DARPA)

DARPA HAPTIX program: restoring naturalistic hand function and sensation to amputees

The last decade has seen tremendous progress in the development of mechatronic prosthetic hands capable of human-like grasp and manipulation. To take advantage of these new capabilities, users require new methods for controlling and sensing the complex actions of the prosthesis. Without tactile and proprioceptive feedback, even the most advanced prostheses remain numb, like a tool rather than a bodily limb, a factor that impairs the limbs' effectiveness and user acceptance.

To address these limitations, DARPA created the Hand Proprioception and Touch Interfaces (HAPTIX) program. This 5-year program began in 2014 with the goal of creating fully implantable neural interface microsystems to extract volitional control signals from muscles and nerves and provide tactile and proprioceptive feedback via patterned microstimulation of sensory nerves. Teams are also creating and validating novel outcome metrics for quantifying the effects of the HAPTIX system in improving motor and sensory function, reducing pain, and improving quality of life. During the first year of the program, HAPTIX teams demonstrated several core capabilities, working with human amputees to evaluate new types of intramuscular electromyography (EMG) electrodes that permit long-term recording of high quality myoelectric control signals. Psychophysics studies were also performed to evaluate the tactile and proprioceptive sensations elicited by peripheral nerve stimulation. In summary, HAPTIX teams are making excellent progress toward fulfilling the promise to provide amputees with state-of-the-art prosthetic hands with naturalistic control and sensory functions. The next phase of the program will focus on integrating components into a complete system, in preparation for a year-long take-home trial to evaluate and refine the technology for community use.

15:30 – 16:30 **Scott Delp**, Stanford University

Optimizing Human Performance

One of the challenges in developing wearable robotic systems is understanding the interaction between wearable robots and human users. To address this challenge we are developing an optimization framework to synthesize a realistic human movement, assess how actuation provided by a wearable robot interacts with actuation provided by human muscles, and to optimize performance of the human-machine system. My laboratory is implementing this optimization framework in OpenSim, a widely used software package for analysis of human movement. I will discuss our most recent developments and present challenges to the community that must be met to advance our field.

Student Awards

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Nathalie van Beek, *Vrije Universiteit Amsterdam*
Kadie Wright, *University of New Brunswick*

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Diego Guarin, McGill University
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Kelsey Gsell, University of Guelph
Eduardo Rocon, CSIC
Eneida Y Suda, University of São Paulo
Laura Diamond, The University of Melbourne
Taiichi Koseki, Hiro-o Orthopedics Clinic
Jose Alvarez Martin, University of Glasgow

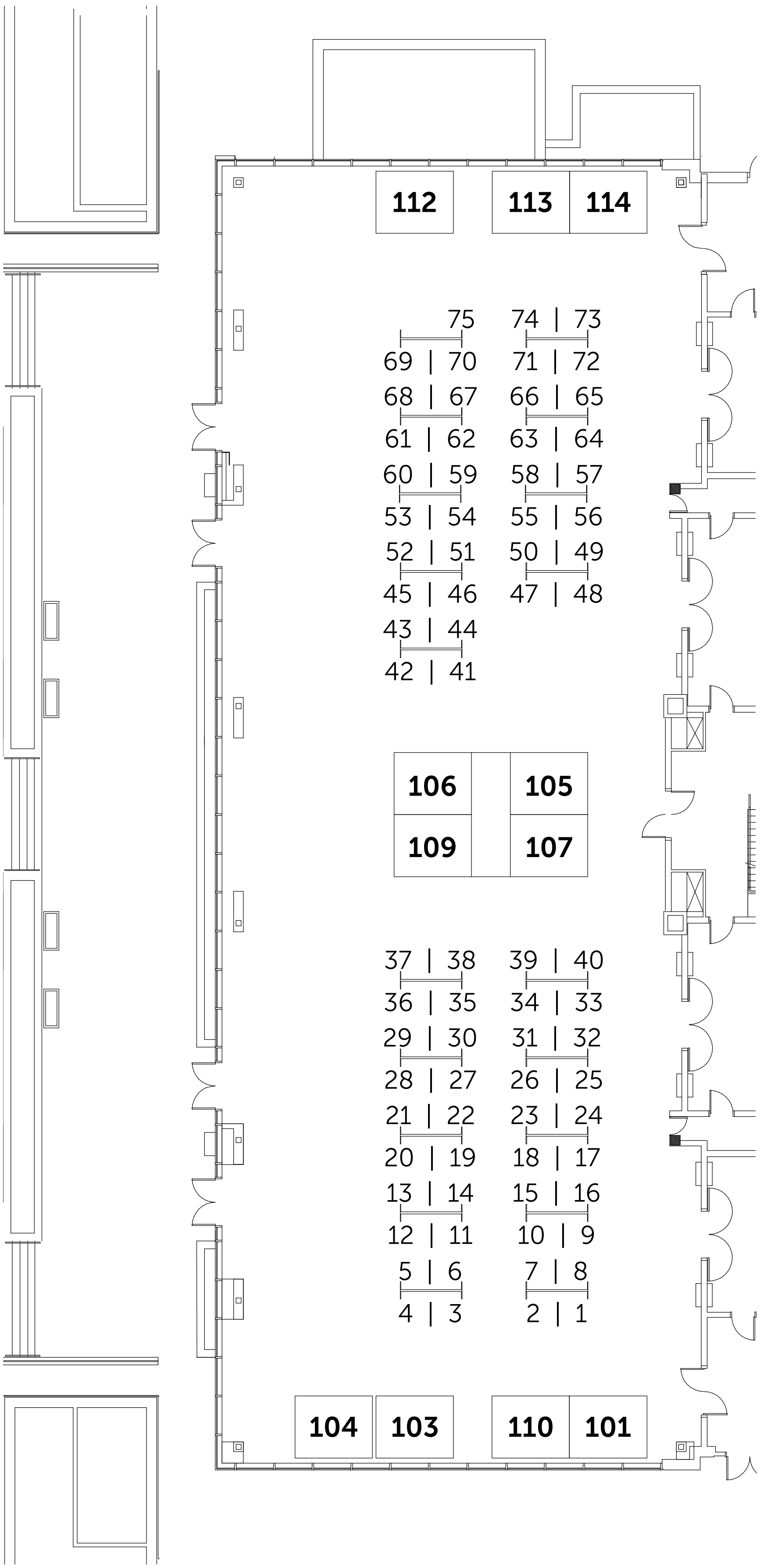
Motorola Mobility Challenge Award Winners

Motorola Mobility
Foundation

WHITNEY YOUNG INNOVATION TEAM: PROJECT TROUVE

Martin Lozano
Emilio Reyes
Christian Vasquez
Samantha Bachand
Ricardo Reyes
Pablo Sanchez

Please visit the Award winners' poster presentation on Thursday, July 7 - poster number P2-75



Brain Vision, LLC	*Booth 103*
BTS Bioengineering	*Booth 109*
Delsys Inc	*Booth 107*
International Society of Biomechanics (ISB)	*Booth 104*
The MotionMonitor	*Booth 101*
Noraxon USA, Inc.	*Booths 113 - 114*
OT Bioelettronica	*Booth 106*
TMS International	*Booth 112*
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ViTRAK Systems Inc.	*Booth 105*

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[1]University of New Brunswick, [2]National Institute of Technology

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Robert Seibt[1], Monika Rieger[1], Benjamin Steinhilber[1]
[1]University Hospital Tübingen

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[1]Universidade Estadual de Londrina/Instituto Federal do Paraná, [2]Laboratory of Biomechanics and Clinical Epidemiology, PAIFIT Research Group, [3]Institute of Applied Medical Engineering

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[1]Karolinska Institutet

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[1]The Univercity of Electro-Commnications

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[1]University of Waterloo

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[1]Vrije university (VU), [2]Radboud University Nijmegen Medical Centre

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[1]Chulalongkorn University

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[1]Truman State University

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[1]Northwestern University

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[1]University of Applied Sciences and Arts of Southern Switzerland, [2]University of Pavia

B - MOTOR PERFORMANCE AND SPORTS SCIENCE

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Jonas Markström[1], Eva Tengman[1], Helena Grip[1], Lina Schelin[1], Charlotte Häger[1]

[1]*Umeå University*

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Masahiro Edo[1], Sumiko Yamamoto[2]

[1]*Bunkyo Gakuin University,* [2]*International University of Health and Welfare*

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Anthony Ciccone[1], Cory Schlabs[1], Joseph Weir[1]

[1]*University of Kansas*

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Caluê Papcke[1], Keith Sato[1], Lisandra Edimundo[1], Eddy Krueger[2], Percy Nohama[1], Eduardo Scheeren[1]

[1]*Pontificia Universidade Católica do Paraná,* [2]*Universidade Tecnológica Federal do Paraná*

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Lin Xu[1], Chiara Rabotti[1], Massimo Mischi[1]

[1]*Eindhoven University of Technology*

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[1]National Yang Ming University

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Joseph Pliner[1], Naira Campbell-Kyureghyan[1]

[1]*University of Wisconsin-Milwaukee*

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Martin Asker[1], Lena Holm[1], Henrik Källberg[1], Markus Waldén[2], Eva Skillgate[1]

[1]*Karolinska Institutet, Institute of Environmental Medicine,* [2]*Linköping University*

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Martin Asker[1], Lena Holm[1], Henrik Källberg[1], Markus Waldén[2], Eva Skillgate[1]

[1]*Karolinska Institutet, Institute of Environmental Medicine,* [2]*Linköping University*

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[1]*Yonsei University*

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Liane Macedo[1], Daniel Borges[1], Caio Alano Lins[1], Jamilson Brasileiro[1]

[1]*Federal University of Rio Grande do Norte*

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Daniel Borges[1], Liane Macedo[1], Caio Lins[1], Jamilson Brasileiro[1]

[1]*UFRN*

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Manuele Jardim Pimentel[1], Rodrigo Marcel Valentim da Silva[1], Daniel Tezoni Borges[1], Liane de Brito Macedo[1], Jamilson Simões Brasileiro[1]

[1]*Universidade Federal do Rio Grande do Norte*

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Nicholas DeCastro[1], Tom Wu[1], Pamela Russell[1], Kathleen Laquale[1]

[1]*Bridgewater State University*

P1-B-27 ***Computer mouse design and ergonomic mouse pads influence wrist angle, forearm extensor and upper trapezius muscle activity***

Sharika Udipi[1], Kylie Tucker[1], Sharika Udipi[1], Hweekoon Yeo[1], Torbjorn Selas[1], Michel Coppieters[2]

[1]*The University of Queensland,* [2]*Vrije Universiteit Amsterdam*

P1-B-28 *Kinesio Taping promotes neither immediate nor delayed changes in neuromuscular performance in healthy, active women*

Jamilson Brasileiro[1], Caio Lins[1], Daniel Borges[1], Karinna Costa[1], Liane Macedo[1]

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C - SENSORIMOTOR CONTROL

P1-C-29 *Quantification of the expression of the flexion synergy using reach kinematics in pediatric hemiplegia*

Nayo Hill[1], Julius Dewald[1]

[1]Northwestern University

P1-C-30 *Priming the motor cortex by electrical stimulation of back muscles*

Edith Elgueta Cancino[1], Hugo Masse-Alarie[2], Siobhan Schabrun[1], Paul Hodges[1]

[1]University of Queensland, [2]Université Laval

P1-C-31 *Effect of Movement Velocity on Hip and Knee Muscle Onset Latency During a Single Leg Squat in Sunjects with and Without Patellofemoral Pain Syndrome*

Ignacio Orozco-Chavez[1], Guillermo Mendez-Rebolledo[1]

[1]University of Talca

P1-C-32 *Contributions of vestibular and somatosensory systems to quiet standing in sighted and congenitally blind people*

Masaki Iguchi[1], Hideki Kadone[2], Richard Shields[3]

[1]Tsukuba University of Technology, [2]University of Tsukuba, [3]University of Iowa

P1-C-33 *Decomposition of gyroscopic trunk sway for clinical assessment of standing balance*

Tomas Bäcklund[1], Fredrik Ohberg[1], Helena Grip[1], Nina Sundström[1]

[1]Umeå University

P1-C-34 *Relationship between center of pressure and medio-lateral directions in the functional reach test: clinical projection in spinal cord injury*

J. Claudio López-Monárdez[1], Valeska Gatica-Rojas[1]

[1]Universidad de Talca

P1-C-35 *Effect of body weight support on muscle activities during walking and running using a lower body positive pressure treadmill in healthy adults*

Kiyotaka Kamibayashi[1], Shodai Yoshida[1], Taku Wakahara[1], Kojiro Ishii[1], Yoshinobu Ohira[1]

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P1-C-36 *The effect of acute pain and motor learning on sensorimotor integration and accuracy using a motor tracing task*

Erin Dancey[1], Bernadette Murphy[1], Paul Yielder[1], Danielle Andrew[1]

[1]UOIT

P1-C-37 *Effect of neuromuscular electrical stimulation on motor cortex excitability upon release of tonic muscle contraction*

Kenichi Sugawara[1], Shigeo Tanabe[1], Tomotaka Suzuki[2], Toshio Higashi[3]

[1]Fujita Health University, [2]Kanagawa University of Human Services, [3]Nagasaki University

P1-C-38 *Trunk muscle activation during position-control tasks in sitting*

Martin Eriksson Crommert[1], Kylie Tucker[2], Paul Hodges[2]

[1]University Health Care Research Centre, Örebro University, [2]The University of Queensland

P1-C-39 *Altered integration of proprioceptive information for balance control is linked with prospective falls*

Wolbert van den Hoorn[1], Graham Kerr[2], Jaap van Dieën[3]

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D - REHABILITATION TECHNOLOGIES

P1-D-40 *Spike timing-dependent plasticity in lower-limb muscles after incomplete spinal cord injury*

Mike Urbin[1], Monica Perez[1]

[1]University of Miami School of Medicine

P1-D-41 *Distributed stimulation to augment force evoked with functional electrical stimulation*

Alie Buckmire[1], Andrew Fuglevand[1], Danielle Lockwood[1]

[1]University of Arizona

P1-D-42 *Long latency responses induced by Robotic Neuromodulatory Rehabilitation System for Paired Associative Stimulation*

Euisun Kim[1], Jun Ueda[1], Minoru Shinohara[1], Ilya Kovalenko[1]

[1]Georgia Institute of Technology

P1-D-43 *'Off-the-shelf' foot orthoses change knee load during walking in people with patellofemoral pain and mobile feet*

Natalie Collins[1], Harvi Hart[2], Jason Bonacci[3], Bill Vicenzino[1], Kay Crossley[2]

[1]The University of Queensland, [2]La Trobe University, [3]Deakin University

P1-D-44 *Activity-dependent axonal hyperpolarization contributes to NMES-induced contraction fatigability*

Minh Luu[1], David Collins[1], Kelvin Jones[1]

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P1-D-45 *Performance and brain activation during slow speed and anatomical motion movie observation*

Akio Ueda[1], Hiroshi Kurumadani[1], Toru Sunagawa[1]

[1]Hiroshima University

P1-D-46 *Evidence-based prescription of shoulder rehabilitation exercises as determined by EMG*

David Hawkes[1], Simon Frostick[1]

[1]University of Liverpool

P1-D-47 *The effect of circumferential pressure on soleus muscle stiffness*

James Agostinucci[1], Peter Blanpied[1]

[1]University of Rhode Island

P1-D-48 *Effects on cervical spine kinematics following Ergo-Motor intervention: an integrated approach combining motor control training and ergonomics*

Sharon Tsang[1], Billy CL So[1], LK Hung[2], SW Law[2], Grace PY Szeto[1]

[1]The Hong Kong Polytechnic University, [2]Chinese University of Hong Kong

P1-D-49 *Validity of estimation of pelvic floor muscle activation through transperineal ultrasound imaging in women*

Cindy Auchincloss[1], Stephanie Thibault-Gagnon[1], Ryan Graham[2], Linda McLean[2]

[1]Queen's University, [2]University of Ottawa

P1-D-50 *System Identification of Two Degrees of Freedom EMG-Force at the Hand-Wrist Using Dynamic Models*

Chenyun Dai[1], Carlos Martinez-Luna[2], Thane Hunt[2], Ziling Zhu[1], Todd Farrell[2], Edward Clancy[1]

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P1-D-51 *In vivo characterization of muscle viscoelastic properties using shear wave elastography*

Allison Wang[1], Eric Perreault [1], Sabrina Lee[1]

[1]Northwestern University

P1-D-52 *Reorganization of neuromuscular coordination when learning new cycling tasks*

Diego Torricelli[1], Cristiano De Marchis[2], Daniel Nemati Tobaruela[3], Filipe Barroso[1], Jose Pons[1]

[1]Consejo Superior de Investigaciones Cientificas, [2]Università Roma Tre, [3]University Carlos III

E - MOVEMENT DISORDERS

P1-E-53 *Changes in the respiratory and the stomatognathic system caused by idiopathic scoliosis*

Saulo Fabrin[1], Bárbara de Lima Lucas[1], Edson Donizetti Verri[1], Eloisa Maria Gatti Regueiro[2], Evandro Marianetti Fioco[1], Marcelo Palinkas[1], Danilo Stefani Esposto[1], Nayara Soares[1], Oswaldo Stamato Taube [1], Simone Ceilio Hallak Regalo[1]

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P1-E-54 *Functional analysis of the stomatognathic system in individuals with fibromyalgia syndrome*

Victor Nepomuceno[1], Bruno Ferreira[1], Gabriel Silva[1], Marcelo Palinkas[1], Oswaldo Luiz Taube[2], Selma Siéssere[1], Marisa Semprini[1], Simone Cecilio Regalo[1]

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P1-E-55 *Effects of regionally selective activation of trunk muscles on dimensions of upper and lower thoraxes during respiration*

Riho Higashi[1], Naoya Nishida[2], Tatsuya Ishizuka[3], Yukisato Ishida[4], Fujiyasu Kakizaki[4]

[1]IMS group Itabashi Chuo Medical Center, Tokyo, Japan, [2]Sonoda Second Hospital, [3]IMS group Tokyo Nephro Urology Center Yamato Hospital, [4]Bunkyo Gakuin University

P1-E-56 *Evaluation and analysis of respiratory muscle strength of patients with multiple sclerosis*

Marília Martins de Oliveira Pupim[1], Michelle Bazilio Milan[1], Saulo Fabrin[2], Danilo Stefani Esposto[2], Gabriel Pádua da Silva[2], Evandro Matianetti Fioco[2], Simone Cecilio Hallak Regalo[2], Edson Donizetti Verri[2]

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P1-E-57 ***Analysis of the chewing in women post-mastectomy - pilot study***

Danilo Esposto[1], Marcelo Palinkas[2], Saulo Fabrin[3], Bárbara Lucas[4], Edson Verri[2], Paulo Vasconcelos[2], Vânia Ferreira[1], Elaine Guirro[1], Eduardo Chedid[2], Simone Regalo[2]

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P1-E-58 ***Length dependence of the shear elastic properties of the biceps brachii after stroke***

Andrew Lai[1], Nina Suresh[1], Xiaogang Hu[2], Zev Rymer[1]

[1]Northwestern University, [2]University of North Carolina/ North Carolina State University

P1-E-59 ***Acute Intermittent Hypoxia Augments Upper Limb Neuromotor Function in Persons with Spinal Cord Injury***

Milap Sandhu[1], Babak Afsharipour[1], Ghulam Rasool[1], Andres Cardona[1], William Zev Rymer[1]

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P1-E-60 ***Evaluation of the masticatory and cervical muscles in women post-mastectomy - pilot study***

Danilo Esposto[1], Marcelo Palinkas[2], Saulo Fabrin[2], Bárbara Lucas[3], Edson Verri[2], Paulo Vasconcelos[2], Vânia Ferreira[1], Elaine Guirro[1], Eduardo Chedid[2], Simone Regalo[2]

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P1-E-61 ***Effect of total knee arthroplasty on balancing capacity after sudden perturbation in patients with bilateral knee osteoarthritis***

Gréta Szabó[1], Gergely Nagymáté[1], Rita Kiss[1]

[1]Budapest University of Technilogy and Economics

P1-E-62 ***Spastic Semitendinosus Muscle of Cerebral Palsy Patients Tested Intra-operatively Does Get Affected by Epimuscular Myofascial Force Transmission but Shows no Abnormal Mechanics***

Can Yucesoy[1], Cemre Su Kaya[1], Yener Temelli[2], Filiz Ates[3]

[1]Bogazici University, [2]Istanbul University, [3]Waseda University

P1-E-63 ***Influence of the ataxia on the masticatory efficiency***

Bruno Ferreira[1], Ligia Napolitano Gonçalves[2], Veridiana Arnoni[2], Gabriel Silva[1], Camila Gonçalves[2], Isabela Regalo[2], Sandra Rancan[2], Oswaldo Stamato Taube[2], Selma Siéssere[2], Simone Hallak Regalo[2]

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P1-E-64 ***Characterization of Passive Muscle Viscoelastic Properties in Hemiplegic Stroke***

Ghulam Rasool[1], Allison Wang[2], William Rymer[1], Sabrina Lee[2]

[1]Rehabilitation Institute of Chicago, [2]Northwestern University

P1-E-65 ***Older and young adults with chronic low back pain present increased back muscle fatigue***

Alexandre Nowotny[1], Edgar Vieira[2], Marcos Cabrera[3], Leandro Altimari[4], Andreo Aguiar[1], Adriana Carvalho[1], Marcio Oliveira[1], Rubens da Silva[1]

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F - MOTOR UNITS

P1-F-66 ***Motor unit firing pattern of vastus lateralis muscle and its association with the strength capacity in the elderly***

Kohei Watanabe[1], Ales Holobar[2], Motoki Kouzaki[3], Madoka Ogawa[4], Hiroshi Akima[4], Toshio Moritani[3]

[1]Chukyo University, [2]University of Maribor, [3]Kyoto University, [4]Nagoya University

P1-F-67 ***Effect of posture on motor unit control investigated by decomposition techniques in adults after stroke***

Mizuki Daimon[1], Koji Ohata[1], Ryosuke Kitatani[1], Yu Hashiguchi[1], Ayaka Maeda[1], Shihomi Kawasaki[1], Masanori Wakida[1]

[1]Kyoto university

P1-F-68 ***Evaluation of neuromuscular activation and force tracking accuracy during isometric sine-wave force exertion***

Aya Tomita[1], Hiroshi Akima[1]

[1]Nagoya University

P1-F-69 ***Cutaneous post-synaptic potentials from the in vivo cat***

Christopher Thompson[1], Michael Johnson[2], Matthieu Chardon[2], Francesco Negro[3], Dario Farina[3], Charles Heckman[2]

[1]Temple University, [2]Northwestern University, [3]University Medical Center, Georg-August University

P1-F-70 ***Motor unit synchronization during linear motor commands***

Sarah Hruby[1], Hsaun Kang[1], Ina Joshi[1], David Hurley[1], Francesco Negro[2], Darion Farina[2], Jules Dewald[1], Charles Heckman[1], Christopher Thompson[3]

[1]Northwestern University, [2]Georg-August University, [3]Temple University

P1-F-71 ***Motor axon excitability properties of the human gastrocnemius and soleus muscles***

Cliff Klein[1], Chen Ning Zhao[1], Hui Liu[1], Ping Zhou[1]

[1]Guangdong Provinical Work Injury Rehabilitation Center

P1-F-72 ***Evaluation of the neuromuscular fatigue in long-lasting cardiothoracic surgeries, using multi-channel EMG***

Tiago Lopes[1], Miguel Correia[1]

[1]Faculdade de Engenharia da Universidade do Porto

G - NEURAL ENGINEERING

P1-G-73 ***Feasibility study on effects of free bubble insole for walking***

Tohru Kiryu[1], Toshio Murayama[2], Kentaroh Yamaguchi[3], Kensuke Otsuka[3]

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P1-G-74 ***Mitigating the effect of wrist kinematics on pattern recognition control***

Adenike Adewuyi[1], Levi Hargrove[1], Todd Kuiken[1]

[1]Northwestern University

P1-G-75 ***Towards the restoration of hand function using fully wireless cortically-controlled functional electrical stimulation***

Juan Gallego[1], Stephanie Naufel[1], Steven Lanier[1], Lee Miller[1]

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NOTES

A - EMG RECORDING, MODELING, AND SIGNAL PROCESSING

P2-A-1 *A Systematic Analysis of the Relationship between Fine Wire and Surface Electromyography Onset Detection with and without the Teager Kaiser Energy Operator*

Andrew Tweedell[1], Courtney Webster[1], Matthew Tenan[1]

[1]Army Research Laboratory

P2-A-2 *Continuous frequency change of SEMG for a transition period between knee extension and knee flexion during pedaling*

Kenichi Kaneko[1], Hitoshi Makabe[2], Kazuyuki Mito[3], Kazuyoshi Sakamoto[3]

[1]Fuji University, [2]Yamagata Prefectural University of Health Sciences, [3]University of Electro-Communications

P2-A-3 *An Investigation of the Surface Electromyography-to-Force Relationship During Fatiguing Static Elbow Flexion*

Paul Leuty[1], Chad Sutherland[1], Jim Potvin[2], Joel Cort[1]

[1]University of Windsor, [2]McMaster University

P2-A-4 *Wearable wireless multichannel sEMG acquisition system*

Luigi Cerone[1], Marco Gazzoni[1]

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P2-A-5 *Geometry-related variations in CMAP distribution over the soleus: a simulation study*

Alberto Botter[1], Taian Vieira[1]

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P2-A-6 *Spike shape analysis of mechanomyogram during linear torque decrement in fresh and fatigued muscle*

Renata Andrzejewska[1], Artur Jaskólski[1], Jarosław Marusiak[1], Anna Jaskolska[1], Claudio Orizio[2]

[1]University School of Physical Education, Wroclaw, [2]University of Brescia

P2-A-7 *A closed-loop neuromuscular simulation can provide insights into the origins and task-dependencies of force fluctuations.*

Akira Nagamori[1], Chris Laine[1], Kian Jalaleddini[1], Francisco Valero-Cuevas [1]

[1]University of Southern California

P2-A-8 *Evaluation of external anal sphincter innervation asymmetry in obstetrics*

Vita Zacesta[1], Dace Rezeberga[1], Haralds Plaudis[2], Kristina Drusany-Staric[3], Corrado Cescon[4]

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B - MOTOR PERFORMANCE AND SPORTS SCIENCE

P2-B-9 *The Effects of Fatigue in Backward Skating in Ice Hockey*

Tom Wu[1], David Pearsall[2], Pamela Russell[1], Yuko Imanaka[1]

[1]Bridgewater State University, [2]McGill University

P2-B-10 *The Effects of Load Mass Variations on Front and Back Squat Movement Coordination Pattern*

Tom Wu[1], Joo-sung Kim[2]

[1]Bridgewater State University, [2]Texas State University

P2-B-11 *Effect of whole-body vibration on isokinetic performance and muscle activation in individuals submitted to Anterior Cruciate Ligament reconstruction*

Karinna Costa[1], Daniel Borges[1], Liane Macedo[1], Caio L[1], Samara Melo[1], Jamilson Brasileiro[1]

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P2-B-12 *Effects of low level laser therapy on electromyographic activity after muscular fatigue: randomized, controlled, and blinded trial*

Rodrigo Marcel Valentim da Silva[1], Manuele Jardim Pimentel[1], Liane de Brito Macedo[1], Daniel Tezoni Borges[1], Jamilson Simões Brasileiro[1]

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P2-B-13 *Relationship between the transverse palmar arch in the hand and the intrinsic hand muscles during reach-to-grasp motion for an object of different size*

Kurumadani Hiroshi[1], Okajo Misuho[1], Sunagawa Toru[1]

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P2-B-14 *Supersonic Shear Imaging is a non-invasive method to early detect muscle damage*

Lilian Lacourpaille[1], Antoine Nordez[1], Valentin Doguet[1], Ricardo Andrade[1], François Hug[1], Gaël Guilhem[2]

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P2-B-15 *Effect of unilateral fatigue in the knee extensors on crank power during sprint cycling*

Rosie Bourke[1], Guillaume Millet[2], David Rouffet[1]

[1]Victoria University, [2]University of Calgary

P2-B-16 *The effect of external support on force and COP performance after ankle plantarflexors fatigue in athletes with ankle instability during lateral drop landing*

Cheng-Feng Lin[1], Wan-Ching Lee[1]

[1]National Cheng Kung University

P2-B-17 *The influence of kinesio tape and ankle brace on the lower extremity joint motion in fatigued unstable ankles during lateral drop landing*

Cheng-Feng Lin[1], Wan-Ching Lee[1]

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P2-B-18 *Development of a Diagnostic System for Shoulder Disorder Using Musculoskeletal Simulation*

Po-Hsun Huang[1], Wo-Jan Tseng[2], Bing-Shiang Yang[1]

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P2-B-19 *Reliability of the CANTAB cognitive assessment battery over short duration repeated measurements*

Michael Williams-Bell[1], Shawna Buren[2], Steven Passmore[3], Bernadette Murphy[2]

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C - SENSORIMOTOR CONTROL

P2-C-20 *The skinny on vibration detection; how to generate skin feedback from the soles of the feet*

Leah Bent[1], Nicholas Strzalkowski[1]

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P2-C-21 *The effects of an 8-week stabilization exercise program on trunk muscle thickness and activation as measured with ultrasound imaging in patients with chronic low back pain*

Christian Lariviere[1], Sharon Henry[2], Dany Gagnon[3], Richard Preuss[4], Jean-Pierre Dumas[5]

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P2-C-23 *Does continuous visual feedback mediate motor learning and consolidation? Insights into landing strategies based on extrinsic and intrinsic information*

Adam Grinberg[1], Dario Liebermann[1]

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P2-C-24 *Unaware motor response induced during biological movement visual stimulus -Physiological effects of an augmented reality system for therapy in sensory-motor disorders-*

Fuminari Kaneko[1], Eriko Shibata[1], Yoshihiro Itaguchi[1]

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P2-C-25 *Low back skin sensitivity has minimal impact on active lumbar spine proprioception and stability in healthy adults*

Shawn Beaudette[1], Katelyn Larson[1], Dennis Larson[1], Stephen Brown[1]

[1]*University of Guelph*

P2-C-26 *Split-Belt Treadmill Adaptation in Transtibial Amputees*

Oliver Kannape[1]

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P2-C-27 *No gender effect in pinch grip coordination after lateral transfer in brain among stroke survivors*

seyed Hadi Salehi[1], Na Jin Seo[1]

[1]*Loyola maymount university*

P2-C-28 *People with chronic low back pain show reduced movement complexity during daily activities*

Leonardo Gizzi[1], Oliver Röhrle[1], Frank Petzke[2], Deborah Falla[2]

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P2-C-29 *The potential functional consequences of the distribution of fat infiltration in the neck muscles*

James Elliott[1], Anneli Peolsson[2], Janne West[2], Rebecca Abbott[1], Ulrika Åslund[2], Anette Karlsson[2], Olof Dahlqvist Leinhard[2]

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P2-C-30 *Measures of local dynamic stability at the ankle joint before and after a fatiguing protocol reveal subsets of polarised behaviours in young healthy adults*

Denise McGrath[1], Christopher Millar[2]

[1]*University College Dublin,* [2]*Ulster University*

E - MOVEMENT DISORDERS

P2-E-31 *Impact of amyotrophic lateral sclerosis in the system stomatognatic*

Ligia Maria Napolitano Gonçalves[1], Jaime Eduardo Cecilio Hallak[2], Bárbara de Lima Lucas[1], Wilson Marques Júnior[2], Marcelo Palinkas[1], Sandra Valéria Rancan[1], Paulo Batista de Vasconcelos[1], Marisa Semprini[1], Selma Siéssere[1], Simone Cecilio Hallak Regalo[1]

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P2-E-32 ***Acupuncture applied to the branches of the facial nerve for the rehabilitation of bell's facial paralysis***

Saulo Fabrin[1], Bárbara de Lima Lucas[1], Edson Donizetti Verri[1], Danilo Stefani Esposto[1], Marcelo Palinkas[1], Edson Alves Barros Jr[2], Michelle Bazilio Milan[2], Evandro Marianetti Fioco[1], Marília Pupim[2], Oswaldo Stamato Taube[1], Simone Cecilio Hallak Regalo[1]

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P2-E-33 ***Finger movement control and associated brain activity responses post-stroke***

Anna-Maria Johansson[1], Helena Grip[2], Andrew Strong[2], Jonas Selling[2], Louise Rönnqvist[3], Carl-Johan Boraxbekk[2], Charlotte Häger[2]

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P2-E-34 ***Concentric and isometric torques are affected by diabetes but the eccentric remains unchanged due to diabetes or polyneuropathy***

Jean Ferreira[1], Isabel Sacco[2], Cristina Sartor[2], Tania Salvini[1]

[1]Federal University of Sao Carlos, [2]University of Sao Paulo

P2-E-35 ***Effect of back pain on trunk strength capacity and muscle activity patterns during isokinetic and sudden trunk loading in adolescent athletes***

Steffen Mueller[1], Josefine Stoll[1], Michael Cassel[1], Juliane Mueller[1], Tilman Engel[1], Frank Mayer[1]

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P2-E-37 ***Functional analysis of lower limbs in individuals infected with the human immunodeficiency virus***

Gabriel Silva[1], Bruno Ferreira[1], Veridiana Arnoni[1], Edson Verri[1], Camila Gonçalves[2], Paulo Vasconcelos[1], Maria Aparecida Vasconcelos[1], Selma Siéssere[1], Isabela Regalo[1], Marisa Semprini[1], Alcyone Machado[1], Simone Cecilio Regalo[1]

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P2-E-38 ***A systematic review of torso motor control impairments in adolescents with idiopathic scoliosis (ais) with implications for the planning of conservative interventions***

Fatemeh Aslanzadeh[1], Eric Parent [2], Brian MacIntosh[2]

[1]University of Calgary, [2]University of Alberta

P2-E-39 ***Effects of low vision and blindness in complex postural***

Nayara Soares[1], Edson Verri[2], Saulo Fabrin[2], Selma Siéssere[1], Victor Rodrigues Nepomuceno[1], Paulo Batista de Vasconcelos[1], Marcelo Palinkas[1], Simone Cecílio Hallak Regalo[1]

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P2-E-40 ***Superficial tissue compression effects in muscle tone of patients with encephalic vascular accident***

Camila Gonçalves[1], Gabriel Silva[2], Bruno Ferreira[2], Veridiana Arnoni[2], Saulo Fabrin[2], Crislaine Lima[3], Vanessa Dias[3], Edson Verri[2], Simone Cecilio Regalo[2]

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P2-E-41 ***Investigation of Oxygenation Difference during Sternocleidomastoid Isometric Contraction for Clients with Mechanical Neck Disorder***

Po-Ching Yang[1], Chia-Chi Yang[2], Yung Chang[2], Lan-Yuen Guo[1]

[1]Kaohsiung Medical University, [2]National Cheng Kung University

P2-E-42 ***Functional analysis of the stomatognathic system in individuals with multiple sclerosis***

Gabriel Silva[1], Bruno Ferreira[1], Veridiana Arnoni[1], Edson Verri[1], Camila Gonçalves[2], Isabela Regalo[1], Selma Siéssere[1], Marisa Semprini[1], Simone Cecilio Regalo[1]

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P2-E-43 ***Midfoot Kinematics During Adult Gait***

Victoria Chester[1], Usha Kuruganti[1], Jeffrey Grant[1]

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P2-E-44 ***The strategies on turning while walking after stroke***

Takahito Nakamura[1], Fumihiko Hoshi[2]

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H - NEUROMECHANICS

P2-H-45 ***Muscle synergies underlying sit-to-stand tasks and their relationship with kinematic characteristics***

Hiroki Hanawa[1], Keisuke Kubota[2], Takanori Kokubun[3], Tatsuya Marumo[4], Keita Murata[5], Fumihiko Hoshi[3]

[1]Higashi Saitama general Hospital, [2]Ishii Clinic, [3]Saitama prefectural University, [4]Ageo Chuou general Hospital, [5]Rehabilitation Amakusa Hospital

P2-H-46 *The importance of feed-forward control in posture stability*

Chihiro Edamatsu[1], Kouki Takahashi[2], Kazuki Kusumoto[1], Masataka Yamamoto[1], Takeshi Miyakawa[3]

[1] Kurashiki University of Science and The Arts, [2]Tokyo Ariake University of Medical and Health Sciences, [3]Kawasaki University of Medical Welfare

P2-H-47 *Threat of perturbation effects on anticipatory postural control*

Angel Phanthanourak[1], Taylor Cleworth[2], Allan Adkin[1], Mark Carpenter[2], Craig Tokuno[1]

[1]Brock University, [2]University of British Columbia

P2-H-48 *Age-related Differences in Neuromuscular and Morphological Characteristics of Plantar Flexors*

Boram Han[1], Dae-Yeon Lee[2], Sung-Cheol Lee[1], Hae-Dong Lee[1]

[1]Yonsei University, [2]Dangnam University

P2-H-49 *Musculoskeletal Modeling driven by Electromyograms processed via Bayesian Filtering Techniques*

Massimo Sartori[1], David Hofmann[2]

[1]University Medical Center, Göttingen, [2]Emory University

P2-H-50 *Shear wave speed measurements during isometric contractions of stroke-impaired medial gastrocnemius and tibialis anterior*

James Pisano[1], Sabrina Lee[1], Kristen Jakubowski[1]

[1]Northwestern University

P2-H-51 *The interaction of biceps and brachioradialis for the control of elbow flexion and extension movements*

Sylvie von Werder[1], Catherine Disselhorst-Klug[1]

[1]Institute for Applied Medical Engineering, RWTH Aachen University

P2-H-52 *Center of pressure mean velocity predicts single limb stance time in experts and novices*

Ana Gomez-del Campo[1], Andrew Sawers[2], Aiden Payne[1], Lena Ting[3]

[1]Georgia Institute of Technology, [2]University of Illinois at Chicago, [3]Emory University

I - NOVEL MEASUREMENT TECHNOLOGIES

P2-I-54 *New Mechanomyogram / Electromyogram Hybrid Transducer for evaluation of muscle contraction during cycling-wheelchair exercise*

Hisao Oka[1], Shin-ichi Fukuhara[2]

[1]OKayama University, [2]University of Medical Welfare

P2-I-55 *Evaluation of Muscle Contraction using 5×5 MMG Array Sensor, 64 Channel sEMG Multichannel Sensor and Ultrasonic Image Equipment*

Hisao Oka[1], Shin-ichi Fukuhara[2]

[1]OKayama University, [2]Kawasaki University of Medical Welfare

P2-I-56 *Inter-rater reliability of kinematic assessment of upper extremity movement based on inertial sensors - A pilot study*

Fredrik Öhberg[1], Tomas Bäcklund[1], Nina Sundström[1], Helena Grip[1]

[1]Umeå University

P2-I-57 *Reliability of helical axis parameters during glonohumeral rotation*

Corrado Cescon[1], Marco Conti[2], Francesco Bozzetti[1], Filippo Ghirlanda[1], Marco Barbero[1]

[1]University of Applied Sciences and Arts of Southern Switzerland, [2]Medsport

P2-I-58 *Development of Flexible Microneedle Electrodes for Recording of Surface EMG*

Kevin Krieger[1], Madeleine Lowery[1], Eoin O'Cearbhaill[1]

[1]University College Dublin

P2-I-59 *Evaluation of shoulder rotation axis during three different tasks*

Corrado Cescon[1], Francesco Bozzetti[1], Filippo Ghirlanda[1], Marco Conti[2], Marco Barbero[1]

[1]University of Applied Sciences and Arts of Southern Switzerland, [2]Medsport

P2-I-60 *Automatic Image Processing of Ultrasound Elastography for Obtaining Muscle Shear Modulus by Removing Connective Tissue Data*

Ellenor Brown[1], Yasuhide Yoshitake[2], Jun Ueda[1], Minoru Shinohara[1]

[1]Georgia Institute of Technology, [2]National Institute of Sports and Fitness, Kanoya

P2-I-61 *Is foot mobility related to age in people with anterior knee pain?*

Natalie Collins[1], Bill Vicenzino[1], Kay Crossley[2]

[1]The University of Queensland, [2]La Trobe University

P2-I-62 *Posture of the head and trunk in sitting: quantification of alignment*

María Sánchez[1], Ian Loram[1], John Darby[1], Paul Holmes[1], Penelope Butler[2]

[1]Manchester Metropolitan University, [2]The Movement Centre

P2-I-63 *Passive and active stiffness of the neck extensor muscles is depth-dependent*

Angela Dieterich[1], Ricardo Andrade[2], Guillaume Le Sant[2], Deborah Falla[1], Frank Petzke[1], Francois Hug[2], Antoine Nordez[2]

[1]University Medical Center Goettingen, [2]University of Nantes

P2-I-64 *A Preliminary Study on Measurement of Surgery Procedures with Multi-Channel Surface EMG signals*

Hideo Nakamura[1], Kenji Yoshida[2], Kenta Takayasu[1]

[1]Osaka Electro-Communication University, [2]Kansai Medical University

P2-I-65 *Real-time ultrasound cervical muscle segmentation: with application to monitoring and diagnosis of cervical dystonia*

Ryan Cunningham[1], Peter Harding[1], Ian Loram[1]

[1]Manchester Metropolitan University

P2-I-66 *Addition of a verbal dual task results in reduced right arm swing while walking and men are more susceptible*

Tim Killeen[1], Christopher Easthope[1], Lilla Lörincz[2], Linard Filli[2], Armin Curt[1], Björn Zörner[1], Marc Bolliger[1]

[1]University Hospital Balgrist, [2]University Hospital Zurich

J - ERGONOMICS

P2-J-67 *Change in the lateral axis of high-heeled shoes on the frontal plane*

Takshi Nakayama[1], Tomokazu Muto[1]

[1]Tokyo University of Technlogy

P2-J-68 *The effect of Palm Supporter to writing for Patients with Essential Tremor*

Kazuyoshi Sakamoto[1]

[1]The University of Electro-Communications

P2-J-69 *The effect of Palm Supporter to writing letters for Patients with Essential Tremor*

Kazuyoshi Sakamoto[1]

[1]The University of Electro-Communications

P2-J-70 *A study of tissue oxygenation in neck and forearm muscles during mobile phone tasks*

Grace Szeto[1], KH Ting[1], Tsun Sum Cheung[1], Cheuk Wing Lai[1], Chi Fai Law[1], Wing Yin Lee[1], Chun Sum Yeung[1]

[1]The Hong Kong Polytechnic University

P2-J-71 *Effects of one-sided loading on trunk muscle activity patterns in healthy subjects and back pain patients*

Juliane Müller[1], Tilman Engel[1], Steffen Müller[1], Martin Wolter[1], Josefine Stoll[1], Frank Mayer[1]

[1]University of Potsdam

P2-J-72 *Estimating Expert-Based Functional Assessment Scores Using Sensor Data*

Fatemeh Noushin Golabchi[1], Giacomo Severini[1], Phil Reaston[2], Mary Reaston[2], Paolo Bonato[1]

[1]Harvard Medical School, [2]Emerge Diagnostics

P2-J-73 *A study of neck muscle activity during mobile phone texting and association with flexion relaxation phenomenon*

Kelvin Pun[1]

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P2-J-74 *The effect of a prolonged standing exposure on lower leg volume and muscle fatigue*

Benjamin Steinhilber[1], Robert Seibt[1], Rudolf Wall[1], Monika Rieger[1]

[1]University Hospital Tuebingen

P2-75 *Whitney Young Innovation Team: Project Trouve*

Martin Lozano[1], Emilio Reyes[1], Christian Vasquez[1], Samantha Bachand[1], Ricardo Reyes[1], Pablo Sanchez[1]

[1]Whitney Young High School

A - EMG RECORDING, MODELING, AND SIGNAL PROCESSING

P3-A-1 *An innovative modular wireless system for the acquisition of surface EMG signals*

Luigi Cerone[1], Enrico Merlo[2], Alberto Botter[1], Taian Vieira[1], Andrea Bottin[2], Marco Gazzoni[1]

[1]Politecnico di Torino - LISiN, [2]OT Bioeletronica s.n.c.

P3-A-2 *Investigation of Force and EMG Measures in Competitive Swimmers*

Usha Kuruganti[1], Victoria Chester[1], Cassandra Mooney[1]

[1]University of New Brunswick

P3-A-3 *Evaluating Decomposition Methods for Electromyographic Characterization of Neuromuscular Disorders*

Meena AbdelMaseeh[1], Daniel Stashuk[1]

[1]University of Waterloo

P3-A-4 *Muscle activation patterns when standing on wedges and being exposed to lateral perturbation*

Yun-Ju Lee[1], Bing Chen[1], Mohan Ganesan[1], Kwan-Hwa Lin[2], Alexander Aruin[1]

[1]University of Illinois at Chicago, [2]Tzu Chi University

P3-A-5 *Errors in RMS amplitude estimation attributable to the Inter Electrode Distance of the surface EMG electrode grids*

Subaryani Soedirdjo[1], Babak Afsharipour[2], Paolo Cattarello[3], Roberto Merletti[4]

[1]Politecnico di Torino, Laboratory of Engineering of Neuromuscular System and Motor Rehabilitation, [2]Northwestern University, [3]Laboratory of Engineering of Neuromuscular System and Motor Rehabilitation, [4]Politecnico di Torino

P3-A-6 *The Hand Function of Stroke Patients in the View of Surface Electromyography*

Petra Bastlova[1], Barbora Kolarova[1], Lucie Szmekova[1], Alois Krobot[1]

[1]Palacky University, Faculty of Health Sciences

P3-A-8 *Effects of core muscle pre-activation on the recruitment of the hip muscles during therapeutic hip exercises*

Sharon Tsang[1], Amanda Lam[1], Melody Ng[1], Cherri Tsui[1], Kiki Ng[1], Benjamin Yiu[1]

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P3-A-9 *Impaired hand function is related to increased alpha band coherence between intermediate deltoid and wrist/finger flexors after stroke: preliminary findings*

Yiyun Lan[1], Jun Yao[1], Jules Dewald[1]

[1]Northwestern University

P3-A-10 *Exploring sex differences in cervical spine muscle activity during sudden head perturbations in hockey players*

Chad Debison-Larabie[1], Bernadette Murphy[1], Michael Holmes[1]

[1]University of Ontario Institute of Technology

P3-A-11 *Accurate identification of motor unit activity during dynamic tasks of the forearm muscles: perspectives for prosthetic control*

Tamas Kapelner[1], Francesco Negro[1], Dario Farina[1]

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P3-A-12 *Identification of sEMG-Torque Dynamics May Reveal the Underlying Control Strategy*

Mahsa Golkar[1], Kian Jalaleddini[2], Robert Kearney[1]

[1]McGill University, [2]University of Southern California

B - MOTOR PERFORMANCE AND SPORTS SCIENCE

P3-B-13 *Electromyographic analysis of the scapular muscles in rehabilitation exercise: a cross-sectional study*

Guillermo Mendez-Rebolledo[1], Marcela Nuñez-Valenzuela[1], Arline Rodriguez-Soto[1], Valeska Gatica-Rojas[1]

[1]University of Talca

P3-B-14 *8-week vibration training of the elbow flexors by force modulation*

Lin Xu[1], Marco Cardinal[2], Chiara Rabotti[1], Bogdan Beju[1], Massimo Mischi[1]

[1]Eindhoven University of Technology, [2]Aspire Academy

P3-B-16 *Different sagittal movements of trunk and pelvis dependent on trunk rotation direction at half-hip free sitting posture: Assessment comparable with gait analysis*

Mio Hayashi[1], Tatsuya Ishizuka[2], Naoya Nishida[3], Kenichiro Nishie[1], Hiroki Tsuchiya[4], Hiroyuki Kobayashi[1], Yukisato Ishida[1], Fujiyasu kakizaki[1]

[1]Bunkyo Gakuin University, [2]IMS group Tokyo Nephro Urology Center Yamato Hospital, [3]Sonoda Second Hospital,, [4]Tachibanadai Hospital

P3-B-17 *Contribution of bilateral asymmetry in hip joint movements and trunk motion to the smooth propulsion in gait of normal adults*

Kenichiro Nishie[1], Hiroyuki Kobayashi[2], Tatsuya Ishizuka[3], Yukisato Ishida[1], Fujiyasu Kakizaki[1]

[1]Bunkyo Gakuin University, [2]IMS Group Shinkatsushika Hospital, Tokyo, Japan, [3]IMS Group Tokyo Nephro Urology Center Yamato Hospital

P3-B-18 ***Is there an age difference in voluntary activation during maximal dynamic contractions with eblow flexor muscles?***

Vianney Rozand[1], Jonathon Senefeld[1], Hamidollah Hassanlouei[1], Sandra Hunter[1]

[1]Marquette University

P3-B-19 ***Influence of an Acute Bout of Self-Myofascial Release on the Expression of Isometric Knee Extension Force and Electromyographic and Mechanomyographic Signals of the Quadriceps Musculature***

David Cornell[1], Kyle Ebersole[1], Elizabeth Ford[1]

[1]University of Wisconsin-Milwaukee

P3-B-20 ***Laterally selective stimulation of laterodorsal muscles affects the bilateral deviation in trunk alignment***

Kengo Sasagawa[1], Yuki Honma[2], Ayumi Mohara[3], Yoshihiro Aramaki[4], Kazuya Tame[5], Tetsuro Hirayama[5], Tatsuya Ishizuka[6], Yukisato Ishida[1], Fujiyasu Kakizaki[1]

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P3-B-21 ***Spatial EMG signal properties in human biceps femoris muscle during running on the treadmill***

Kazuyuki Mito[1], Ryuta Inano[1], Tota Mizuno[1], Naoaki Itakura[1]

[1]The University of Electro-Communications

P3-B-22 ***Relationship between dynamic postural control ability with voluntary sway and passive sway and lower limb muscle activity***

Yusuke Oyama[1], Toshio Murayama[1], Tamaki Ohta[2]

[1]Faculty of Education,University of Niigata, [2]Nekoyama Miyao Hospital

P3-B-24 ***Running related gluteus medius muscle function in health and injury: A systematic review with meta-analysis***

Adam Semciw[1], Rachel Neate[2], Tania Pizzari[2]

[1]The University of Queensland, [2]La Trobe University

P3-B-25 ***Biomechanical Strategies of Drop Jump Depending on Human Knee Extensor Eccentric Strength***

Jeonghoon Oh[1], Sae Yong Lee[1], Sung-Cheol Lee[1], Hae-Dong Lee[1]

[1]Yonsei University

P3-B-26 ***Effect of bilateral fatigue in the knee extensor muscles on crank power during sprint cycling***

Steven O'Bryan[1], Janet Taylor[2], David Rouffet[1]

[1]Institute of Sport Exercise and Active Living (ISEAL), [2]Neuroscience Research Australia

P3-B-28 ***Changes in postural control and dual task performance following an ultramarathon***

Dean Smith[1], Joshua Haworth[2], Eric Brooks[1], Julie Cousins[1]

[1]Miami University - Oxford, [2]Johns Hopkins School of Medicine, Kennedy Krieger Institute

P3-B-29 ***Kinematics Comparison between Dominant and Non-Dominant Lower Limbs in Thai Boxing***

William Trial[1], Tong-Ching (Tom) Wu[1]

[1]Bridgewater State University

P3-B-30 ***Forearm muscle function investigated by EMG in tennis players suffering from tennis elbow***

Omid Alizadehkaiyat[1], Simon Frostick[2]

[1]Liverpool Hope University, [2]University of Liverpool

P3-B-31 ***Neuromuscular efficiency of trunk muscles is decreased during an acute pain episode in low back pain patients***

Stephan Kopinski[1], Martin Wolter[1], Tilman Engel[1], Steffen Müller[1], Frank Mayer[1]

[1]University Outpatient Clinic Potsdam

P3-B-32 ***Drop jump kinematic curves differ for ACL-deficient and ACL-reconstructed individuals ~20 years post-injury compared to controls***

Kim Hébert-Losier[1], Lina Schelin[2], Eva Tengman[2], Jonas Selling[2], Andrew Strong[2], Charlotte Häger[2]

[1]National Sports Complex, [2]Umeå university

C - SENSORIMOTOR CONTROL

P3-C-33 ***Modulations of correlated neural oscillations for improving muscle coactivation control due to repetition and practice***

Nayef Ahmar[1], Minoru Shinohara[1]

[1]Georgia Institute of Technology

P3-C-34 ***Neural control of human precision and power grips***

Toshiki Tazoe[1], Monica Perez[1]

[1]Uniersity of Miami

P3-C-35 ***Test-retest reliability of a novel supine knee joint position sense test.***

Andrew Strong[1], Charlotte Häger[1], Eva Tengman[1], Divya Srinivasan[2]

[1]Umeå University, [2]Virginia Polytech Institute and State University

P3-C-36 *Does the motor cortex contribute to electrically-evoked contractions in humans?*

Emily Ainsley[1], Yoshino Okuma[1], David Collins[1]

[1]*University of Alberta*

P3-C-37 *Is human walking behavior better predicted by energetics or stability: a case-study involving human-structure interactions*

Varun Joshi[1], Manoj Srinivasan[1]

[1]*The Ohio State University*

P3-C-38 *FES Control for Restoring Complex Functional Hindlimb Movements in the Rat*

Maria Jantz[1], Amina Kinkhabwala[1], Juan Gallego[1], Lee Miller[1], Matthew Tresch[1]

[1]*Northwestern University*

P3-C-39 *Muscular reflex responses of trunk and lower limb muscles following unexpected gait perturbations in people with and without back pain*

Tilman Engel[1], Juliane Mueller[1], Stephan Kopinski[1], Konstantina Intziegianni[1], Antje Reschke[1], Steffen Mueller[1], Frank Mayer[1]

[1]*University Outpatient Clinic Potsdam*

P3-C-40 *Impact of neck muscle fatigue on scapulohumeral kinematics in subclinical neck pain pain vs asymptomatic controls*

Mahboobeh Zabihhosseinian[1], Michael Holmes[1], Samuel Howarth[2], Brad Ferguson[3], Bernadette Murphy[1]

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P3-C-41 *Joint learning during dyadic haptic interaction*

Dalia De Santis[1], Edwin Johnatan Avila Mireles[2], Valentina Squeri[2], Pietro Morasso[2], Jacopo Zenzeri[2]

[1]*Northwestern Univeristy and Rehabilitation Institute of Chicago,* [2]*Istituto Italiano di tecnologia*

P3-C-42 *Effects of a compression garment on sensory feedback transmission in the upper limb*

Trevor Barss[1], Greg E Pearcey[2], Bridget Munro[3], E Paul Zehr[2]

[1]*Human Neurophysiology Lab, University of Alberta,* [2]*Rehabilitation Neuroscience Lab, University of Victoria,* [3]*Nike Exploration Team*

P3-C-43 *Human upright, postural control: Is sagital centre of mass location controlled to a prior?*

Ian Loram[1], Vasilios Baltzopoulos[2], Irene Di Giulio[3]

[1]*Ian Loram,* [2]*Brunel University,* [3]*University College London*

D - REHABILITATION TECHNOLOGIES

P3-D-44 *The effects of exercise in combination with other conventional antidepressant therapies in treating individuals suffering with Major Depressive Disorder.*

Joanne Gourgouvelis[1], Paul Yielder[1], Hushyar Behbahani[1], Bernadette Murphy[1]

[1]*University of Ontario Institute of Technology*

P3-D-45 *Effects of flexion-extension in upper and lower cervical spines on the laterality of upper and lower thoracic shapes*

Taiichi Koseki[1], Tetsuro Hirayama[1], Tatsuya Ishizuka[2], Naoya Nishida[3], Tsutomu Fujihara[1], Hirohisa Koseki[1], Yukisato Ishida[4], Fujiyasu Kakizaki[4]

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P3-D-46 *Effects of variation in trunk lateral deviation on respiratory function in relation to thicknesses of rectus abdominis and lateral abdominal group muscles*

Tsutomu Fujihara[1], Michie Okazaki[2], Tetsuro Hirayama[1], Tatsuya Ishizuka[3], Taiichi Koseki[1], Kazuya Tame[1], Tomoko Kawasaki[1], Fumiya Inagaki[1], Hirohisa Koseki[1], Yukisato Ishida[4], Fujiyasu Kakizaki[4]

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P3-D-47 *Difference in the acute effect of kinesthetic illusion induced by visual stimulus and action observation on the upper-limb voluntary movement after stroke: a single-case study*

Toru Inada[1], Fuminari Kaneko[2], Naoki Matsuda[1], Satoshi Koyama[1], Junichi Maruyama[1], Junya Shindo[1]

[1]*Asahikawa Rehabilitation Hospital,* [2]*Sapporo Medical University*

P3-D-48 *ULNAR - Upper Limb functional Assessment and Rehabilitation: tools and methods*

Sofia Marques[1], Pedro Fonseca[2], Ana Rita Pinheiro[3], Claúdia Silva[3], Miguel Correia[1]

[1]*Faculdade de Engenharia da Universidade do Porto, Instituto de Engenharia de Sistemas e Computadores,* [2]*Laboratório de Biomecânica do Porto - LABIOMEP,* [3]*Escola Superior de Tecnologia da Saúde do Porto - Instituto Politécnico do Porto/ Centro de Estudos*

P3-D-49 ***A comparison of three types of neuromuscular electrical stimulation for reducing contraction fatigue of the quadriceps muscles***

Francisca Claveria[1], David Collins[1], Jenny Lou[2]
[1]University of Alberta, [2]University of Toronto

P3-D-50 ***Task-specific movements generated by EMG-FES facilitate cortical beta band modulation for hand rehabilitation in individuals with moderate to severe stroke.***

Kevin Wilkins[1], Julius Dewald[1], Jun Yao[1]
[1]Northwestern University

P3-D-51 ***Nintendo Wii decrease spasticity and improves standing balance in cerebral palsy***

Valeska Gatica-Rojas[1], Ricardo Cartes-Velásquez [2], Guillermo Mendez-Rebolledo[1], Eduardo Guzman-Muñoz[1]
[1]Universidad de Talca, [2]Universidad de Concepción

P3-D-52 ***Onset and cessation timing of seven lower limb muscles during walking in patients with diabetes with and without sensory neuropathy and persons without diabetes***

Jonas Martens[1], Filip Staes[1], Giovanni Matricali[2], Frank Nobels[1], Philip Roosen[3], Jos Tits[4], Kevin Deschamps[1]
[1]KU Leuven, [2]UZ Leuven/KU Leuven, [3]University Ghent, [4]Ziekenhuis Oost-Limburg

P3-D-53 ***Influence of using T-Cane on variability of stride interval at a self-selected gait speed***

Hitoshi Makabe[1], Yuka Takahashi[2], Hitomi Take[3], Kenichi Kaneko[4], Kazuyoshi Sakamoto[5]
[1]Yamagata Prefectural University of Health Sciences, [2]Yabuki Hospital, [3]Shin-Kaminokawa Hospital, [4]Fuji University, [5]University of Electro-Communications

P3-D-54 ***Reproducibility of the motion generated by a master-slave system developed using neuromuscular electrical stimulation based on kinematic parameters***

Naoyuki Kataishi[1], Fuminari Kaneko[1], Eriko Shibata[1]
[1]Sapporo medical university

P3-D-55 ***Effect of Visual Feedback on Quality and Consistency of Upper Limb Movement in Stroke Patients***

Daniel Simonsen[1], Mirjana Popovic[2], Erika Spaich[1], Ole Andersen[1]
[1]Aalborg University, [2]University of Belgrade

P3-D-56 ***Effects of augmented verbal feedback in the ankle electrical activity and torque of typical individuals***

Alessandra Matias[1], Ulisses Taddei[2], Francis Trombini-Souza [3], Jane Pires [2], Renan Calori[2], João Daré[2], Milene Dalfolo[2], Fernanda Ribeiro[2], Pamela Santana[2], Rafael Inoue[2], João Pedro Panighel[2], Isabel Sacco[2]
[1]USP, [2]University of Sao Paulo - USP, [3]School of Physical Therapy, University of Pernambuco

E - MOVEMENT DISORDERS

P3-E-57 ***Influence of the Mandibular Tori in the stomatognathic system function***

Laíse Angélica Mendes Rodrigues[1], José Mendes da Silva[1], Cássia Pérola dos Anjos Braga Pires[1], Graziela de Luca Canto[2], Paulo Batista de Vasconcelos[3], Simone Cecilio Hallak Regalo[3]
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P3-E-58 ***Latissimus Dorsi, Maximus Gluteus And Biceps Femoris Activation In People With Sacroiliac Joint Dysfunction***

Laura Sánchez[1], Carolina Ramírez[1], Ana Beatriz Oliveira[2]
[1]Industrial University of Santander, [2]Federal University of Sao Carlos

P3-E-59 ***Subject-specific classification of startle elicited by postural perturbation***

Rosalind Heckman[1], Eric Perreault[1]
[1]Northwestern University

P3-E-60 ***Analysis of electromyographic fatigue of masticatory muscles in osteoporotic individuals***

Veridiana Arnoni[1], Luiz Gustavo Sousa[1], Paulo Vasconcelos[1], Bruno Ferreira[1], Marcelo Palinkas[1], Marisa Semprini[1], Priscila Scalize[1], Oswaldo Luiz Taube[1], Bárbara de Lima Lucas[1], Simone Cecilio Hallak Regalo[1], Selma Siéssere[1]
[1]University of Sao Paulo, Ribeirao Preto

P3-E-61 ***EMG analysis of cervical muscles after acupuncture in women with dysfunction temporomandibular***

Odinê Maria Rêgo Bechara[1], Marcelo Palinkas[1], Marisa Semprini[1], Bárbara de Lima Lucas[1], Paulo Batista de Vasconcelos[1], Selma Siéssere[1], Simone Cecilio Hallak Regalo[1], César Bataglion[1]
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P3-E-62 ***Assessing muscular activation of patients with specific low back pain during daily activities***

Michael Ferdinand Bergamo[1], Catherine Disselhorst-Klug[1]

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P3-E-63 ***Linear and Rotational Acceleration of the Head on Snowboard Beginner's Falls during Freestyle Snowboarding***

Toshihiko Hashimoto[1]

[1]Ryotokuji University

P3-E-64 ***Relationship between co-contraction ratio and knee adduction moment in knee osteoarthritis subjects***

Luiz Fernando Approbato Selistre[1], Theresa Nakagawa[1], Glaucia Gonçalves[1], Marina Petrella[1], Stela Mattiello[1], Richard Jones[2]

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P3-E-65 ***Quantification of head movement when testing segmental trunk control***

María Sánchez[1], Ian Loram[1], John Darby[1], Paul Holmes[1], Penelope Butler[2]

[1]Manchester Metropolitan University, [2]The Movement Centre

P3-E-66 ***Impact of rheumatoid arthritis in stomatognathic system of the women***

Marcelo Palinkas[1], Bárbara de Lima Lucas[1], Marisa Semprini[1], Oswaldo Luiz Satamto Taube[2], Laíse Angélica Mendes Rodrigues[3], Selma Siéssere[1], Simone Cecilio Hallak Regalo[1]

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K - MUSCLE PHYSIOLOGY

P3-K-67 ***The effect of carbohydrate supplementation to muscle fatigue trend in training of table tennis***

Mai Kitamura[1], Kei kamijima[2], Yukihiko Ushiyama[1], Tohru Kiryu[1]

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P3-K-68 ***Influence of data precision on quantifying skeletal muscle movement in ultrasound images***

Diego Miguez[1], Ian Loram[1], Emma Hodson-Tole[1], Peter Harding[1]

[1]Manchester Metropolitan University

P3-K-69 ***Muscle material properties of stroke-impaired plantarflexor muscles***

Kristen Jakubowski[1], Ada Terman[1], Ricardo Santana[1], Sabrina Lee[1]

[1]Northwestern University

P3-K-70 ***Effects of rheumatoid arthritis in masticatory cycles of the women***

Simone Cecilio Hallak Regalo[1], Bárbara de Lima Lucas[1], Oswaldo Luis Stamato Taube[2], Laise Angélica Mendes Rodrigues[1], Selma Siéssere[1], Isabela Hallak Regalo[1], Marisa Semprini[1], Marcelo Palinkas[1]

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P3-K-71 ***Impact of complete implant-supported dentures anchored in the zygomatic bone in stomatognathic system***

Marcelo Palinkas[1], Moara de Rossi[1], Carla Santos[1], Marisa Semprini[1], Lígia Oliveira [1], Selma Siéssere[1], Isabela Regalo[1], Edmilson Oliveira[1], Reginaldo Migliorança[1], Simone Cecilio Regalo[1], Barbara Lucas[1]

[1]University of Sao Paulo, Ribeirao Preto

P3-K-72 ***Fat infiltration of the Paretic Upper Limb in Individuals with Chronic Hemiparetic Stroke: Preliminary Results***

Lindsay Garmirian[1], Ryan Schmid[1], Marie Wasielweski[1], Ana Maria Acosta[1], Todd Parish[1], Jules Dewald[1]

[1]Northwestern University

P3-K-73 ***Greater fatigability among type 2 diabetics without neuropathy is not associated with disruption of neuromuscular propagation or corticomotor excitability***

Jonathon Senefeld[1], Alison Harmer[2], Sandra Hunter[1]

[1]Marquette University, [2]University of Sydney

P3-K-74 ***Intra-rater reliability and agreement in the ankle electromyography activity EMG during sit to stand in healthy young adults***

Odair Bacca Ramirez[1], María Patiño Segura[1], Esperanza Herrera Villabona[1], Jose Barela [2]

[1]Industrial University of Santander, [2]Cruzeiro do Sul University

P3-K-75 ***Ageing and electromyographic fatigue patterns of masticatory muscles***

Ligia Franco Oliveira[1], Bárbara de Lima Lucas[1], Marisa Semprini[1], Selma Siéssere[1], Flávia Argentato Cecilio[1], Paulo Batista de Vasconcelos[1], Luiz Gustavo de Sousa[1], Simone Cecilio Hallak Regalo[1], Marcelo Palinkas[1]

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DAY 1 – WEDNESDAY JULY 6

S.1. Neuromechanics of Human Locomotor Stability: Theoretical Insights and Clinical Applications

Inter-limb cutaneous feedback in walking balance: Early responses at the ankle to rapid light touch displacement at the fingertip during walking

John Misiaszek[1], Tania Shiva[1]

[1]University of Alberta

BACKGROUND AND AIM: Light touch of a stable reference prevents subjects from drifting off of a treadmill when walking with eyes closed. In addition, corrective reactions to balance disturbances during walking are modulated when subjects touch a stable reference. Therefore, feedback from the fingertips is suggested to be involved in control of stability during walking. We asked if tactile inputs from the fingertips can initiate, or trigger, balance reactions during walking. Recently, we demonstrated that rapid displacement of a touch surface can induce a balance reaction during standing. However, these reactions were only observed on the first trial suggesting that the expression of these responses were context dependent. Presently, we hypothesized that rapid displacement of a touch surface would trigger similar balance reactions during treadmill walking and that these responses would be observed more frequently than the first trial alone, given the importance of the touch reference to the task of walking with eyes closed. METHODS: 20 participants walked on a treadmill. EMG activity was recorded from 9 muscles including the right tibialis anterior (TA) and soleus (SOL). Electrogoniometer records were obtained from the right elbow, knee and ankle, along with foot contact from both feet. Participants walked at a consistent self-selected speed in 4 conditions: a) eyes open, b) eyes open while touching, c) eyes closed, and d) eyes closed while touching (ECT). Conditions a-c were used as a deception. During ECT participants walked while lightly touching (<1 N) a touch plate for 1 min before touch plate displacements (12.5 mm, 124 mm/s) were unexpectedly introduced at right heel-strike. Displacements were separated by at least 20 steps. Participants received a block of 10 displacements in a

single direction (forward or backward). Half received forward perturbations. RESULTS: All participants responded to the touch plate displacement at heel-strike with activation of ankle muscles in at least two trials. Typically, TA activation was observed following a forward displacement, with a median rate of 7 responses per participant across all 10 trials. SOL activation was typically observed following backward displacement, with a median rate of 6.5 responses per participant across all 10 trials. Response latencies in TA and SOL did not vary from the first [133.75 (±39.05); 125.65 (±46.66) ms] to last responses [136.15 (±43.93); 128.35 (±40.62) ms]. CONCLUSIONS: These findings confirm that light touch sensory cues from a single fingertip are able to generate responses in distant muscles, consistent with a balance reaction during walking. The evoked responses continued to be expressed even when repeated perturbations made the touch reference unreliable. This suggests that cutaneous input from the hands is an important sensory cue in the control of walking balance, particularly when other senses are impaired or the task is challenging.

Perturbation Based Gait Training May Improve the Tradeoff of Stability and Maneuverability in Patients with Lower Limb Injury

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BACKGROUND AND AIM: Lower limb trauma (LLT) significantly impairs walking stability. As a result, individuals with LLT adopt a cautious gait pattern that includes wider step widths (SW). However, maneuverability is an important aspect of community living with many everyday tasks, like navigating a crowded sidewalk, requiring rapid lateral movements. While a wider, less variable SW is considered to be more stable during walking, a narrower, more variable SW is related to greater maneuverability during dynamic movements creating a tradeoff. We present two studies that identify the relationship between stability and maneuverability in individuals with LLT and determine if that relationship can be improved with training. METHODS: To investigate the tradeoff between stability and maneuverability, individuals with LLT and healthy controls navigated a virtual obstacle course which required rapid lateral lane changes through a series of arches. We measured SW mean and variability and the number of transitions where the participant hit an arch. In a separate study, an individual with a unilateral, above-knee amputation

completed an intervention utilizing walking surface pitch and roll oscillations in a virtual environment. We measured SW mean and variability pre and post intervention. RESULTS: Individuals with LLT had more failed transitions in the virtual obstacle course than healthy controls. During the transition movements they maintained wider and less variable SW. Following the intervention, the patient reduced their SW mean and variability, closer to or within normal ranges. This change was accompanied by greater patient reported confidence in their balance and walking ability. CONCLUSIONS: Individuals with LLT maintained wider and less variable steps during the transition movements, suggesting that stability is prioritized over maneuverability, which likely contributed to their reduced performance. This bias toward stability and adoption of a cautious gait pattern likely arise from reduced balance confidence and not having developed appropriate responses to walking perturbations. However, an individual with a unilateral, above-knee amputation was able to normalize their stepping pattern and perceived balance following the perturbation based intervention. This suggests that, although individuals with LLT present with decreased stability leading to cautious gait patterns and a bias towards stability over maneuverability, it appears that perturbation training and exposure to destabilizing situations can assist these individuals in improving their stability and likely their maneuverability as well. ACKNOWLEDGEMENTS NIH 1-R01-HD059844 and DoD/CDMRP/BADER W81XWH-11-2-0222 DISCLAIMER The views expressed herein are those of the authors and do not reflect the official policy or position of Brooke Army Medical Center, U.S. Army Medical Department, U.S. Army Office of the Surgeon General, Department of the Army, Department of Defense or the U.S. Government

Post-stroke deficits in a mediolateral gait stabilization strategy (and a possible intervention)

Jesse Dean[1]

[1]Medical University of South Carolina

BACKGROUND AND AIM: Individuals who have experienced a stroke often exhibit gait instability, as evidenced by an increased fall-risk and fear of falling. Unfortunately, recent large-scale rehabilitation interventions have failed to substantially impact fall-risk, likely due to these interventions not being targeted

toward the mechanisms underlying post-stroke gait instability. The aim of the present study was to identify post-stroke deficits in a control strategy that allows neurologically intact adults to generate a stable gait pattern seemingly so easily. In the longer term, we seek to use these results to design a novel rehabilitation intervention. METHODS: In previous work (and consistent with the work of others), we found that neurologically intact controls (n=16) used a consistent strategy of adjusting their step width based on the mechanical state of the pelvis at the start of a step. We quantified this relationship by calculating the partial correlations between step width and mediolateral displacement of the pelvis relative to the stance foot (r_disp) and mediolateral velocity of the pelvis (r_velocity) at the start of a step. For the present study, we performed the same analysis on data collected from chronic stroke survivors (n=24) walking on a treadmill at their self-selected speed, with the goal of determining whether individual stroke survivors use a similar stabilization strategy. Based on the results (described below), we developed an elastic force-field with the goal of retraining mediolateral foot placement while not interfering with anteroposterior progression. Briefly, our device creates a force landscape in which mediolateral deviations from an adjustable "channel" are resisted by mediolateral forces. In initial proof-of-concept experiments, we tested whether our force-field can be used to strengthen the relationship between step width and pelvis displacement (r_disp) on a step-by-step basis. RESULTS: Among controls, the partial correlation values during normal walking fell within a relatively narrow range. In contrast, most stroke survivors exhibited substantially lower correlation values (see Figure), indicating post-stroke deficits in the normal control strategy of adjusting step width based on the mechanical state of the body. Among uninjured controls (n=8), walking in the force-field consistently increased r_disp (by 0.23 ± 0.11), indicating that step width became more responsive to variance in pelvis displacement. Similarly, in two chronic stroke survivors, the force-field caused increases in r_disp of 0.27 ± 0.07 for paretic steps and 0.19 ± 0.09 for non-paretic steps. CONCLUSIONS: Many stroke survivors lack the normal stabilization strategy of adjusting their steps to account for the body's mechanical state. Future work will investigate whether our force-field has beneficial effects on the use of this strategy with training over a longer time scale.

The effect of balance perturbations after myelopathy related sensory deficits on cortical oscillations during walking

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Joseph Lee[1], Brian Schmit[1]

[1]Marquette University

BACKGROUND AND AIM: The objective of this study was to examine the effect of a balance perturbation on cortical movement related oscillations during walking. Brain activity was recorded using electroencephalography (EEG) while participants were walking on a treadmill and delivered a medial-lateral pull to the waist. We hypothesized that these cortical oscillations, shown in previous studies to be strongly associated with motor control, would shift in magnitude and spatial orientation as a function of sensory integration and motor planning in response to the balance perturbation. METHODS: Ten myelopathy subjects in addition to ten young, healthy, neurologically intact volunteers participated in this study. Participants began each trial standing at rest for 10 s, until a visual cue notified the start of the treadmill up to a self-selected comfortable walking speed. A balance perturbation composed of a medial to lateral pull normalized to 5% of bodyweight was delivered to the subject's waist using a custom cable motor setup. Electromyography (EMG) signals were recorded from the tibialis anterior (TA) and medial gastrocnemius (MG), along with kinematic data from an eight camera Vicon motion capture system. EEG data recorded from a 64 channel active electrode cap setup was preprocessed and analyzed using the Fieldtrip, EEGLAB, and Brainstorm toolboxes. Independent component analysis (ICA) was used to remove blink, EMG and motion artifact. Time frequency decompositions of the cleaned trials were calculated using Mortlet wavelets, time warped to gait events and smoothed in time, before being averaged across epochs. Power values were referenced to the baseline period of standing rest as a percent change in power. RESULTS: Balance perturbations while walking were associated with cortical power modulations in theta, alpha, and beta frequency bands. A large increase in theta and alpha band power was observed throughout the cortex immediately after the balance perturbation, followed by significant beta band power increases identified in frontal, motor areas of the brain (Fz, FCz, $p < 0.05$). Parietal areas of the brain exhibiting this beta band increase were observed to precede the corresponding increase of beta band activity in frontal areas of the cortex. These cortical power increases were observed to be delayed in time in our myelopathy subjects. CONCLUSIONS: The large increase in cortex wide theta band power immediately following the balance perturbation may indicate the escalation of

cortical executive functions in response to the pull. The posterior to anterior sequence of beta band modulation in the cortex suggests an association with sensory integration of the balance perturbation, followed by the creation of a motor plan to prevent falling. The time delay observed in myelopathy subjects may reflect slower processing of the balance perturbation resulting from lower limb sensory deficits caused by compression of the spinal cord.

Cortical Correlates of Locomotor Adaptation to Perturbations of Symmetry

James Finley[1]

[1]University of Southern California

BACKGROUND AND AIM: Walking in the real world often requires us to adapt our walking pattern to changes in the environment. For example, walking on a moving walkway or walking in ski boots each require that we recalibrate our locomotor pattern to maintain balance and move through our environment efficiently. This process, termed locomotor adaptation, is mediated in part by subconscious processes that rely on neural circuits within the cerebellum. Recent studies in the upper extremity have also demonstrated that explicit, strategy-based processes controlled by the prefrontal cortex (PFC) also contribute to adaptation. Whether strategic processes contribute to locomotor adaptation remains to be seen. Since walking typically requires very little conscious effort, one might expect that locomotor adaptation is mediated almost exclusively by cerebellar or spinal circuits. Alternatively, explicit strategies may be used for top-down specification of control objectives related to factors such as balance or energetic cost. Here, we use adaptation to walking on a split-belt treadmill to test the hypothesis that activity in the PFC is associated with responses to perturbations of symmetry. METHODS: Participants walked on a dual-belt treadmill in one of three conditions: a Tied condition when both belts moved at 1.0 m/s, a Right Split condition when the right belt moved at 1.5 m/s and the left belt moved at 0.5 m/s, and a Left Split condition when the right belt moved at 0.5 m/s and the left belt moved at 1.5 m/s. The Split conditions were presented in a quasi-random order in a series of 20, 30 second walking trials separated by 30 seconds of standing. This prevented the participants from anticipating the direction of the impending perturbations and allowed us to

obtain robust estimates of cortical activity due to perturbations of symmetry. The average, normalized difference in step lengths (step length asymmetry) during each walking trial was used as the primary kinematic outcome measure. A continuous wave functional near-infrared spectroscopy system (NIRx Nirsport) was used to measure cortical hemodynamic responses in the PFC during adaptation. RESULTS: By presenting the split-belt perturbation in a randomized order, participants maintained significant levels of step length asymmetry despite minor adaptation within each trial. The participants' response to the perturbations was associated with an increase in activity in the PFC relative to baseline trials when the belts moved at the same speeds. CONCLUSIONS: These results provide evidence that the cortex is indeed involved with monitoring, and possibly mediating, locomotor adaptation to perturbations in the environment. Ultimately, identification of the brain areas mediating adaptation may provide targets for non-invasive brain stimulation techniques to improve the acquisition, reacquisition, or retention of motor skills in pathological conditions such as stroke or Parkinson's disease.

System Identification of the Human Locomotion Control System and Energy-optimal Feedback Control

Varun Joshi[1], Barrett Clark[1], Nidhi Seethapathi[1], Yang Wang[2], Manoj Srinivasan[1]

[1]The Ohio State University, [2]Caterpillar

BACKGROUND AND AIM: Although engineers have built robots that walk and run stably (if barely stably), the control system used by a human to uses to walk and run in a stable manner has not yet been well characterized. Here, we will present three complementary approaches to examining the human walking control system. MEHODS: (1) We fit linear dynamical models to natural variability during steady state walking data to characterize how humans modulate their leg forces as well as foot placement to get back to steady state. (2) We perform 'perturbation experiments' in which human subjects walking steadily are perturbed by unforeseen pulls. We fit similar dynamical models to this data to again characterize how humans modulate their leg force and foot placement. (3) We hypothesize that humans recover from perturbations in a manner that minimizes the effort it takes to get back to steady state. We computed such energy optimal recoveries from various perturbations for two simple models. In addition to walking, we also present results on running, specifically using the first and third approaches, namely fitting models to steady state variability and obtaining optimal feedback control. RESULTS: We find that the linear dynamics inferred from steady state variability and perturbation experiments are qualitatively similar with small quantitative differences, perhaps due to nonlinearity of the controller. We find that small deviations in sideways foot placement during steady walking as well as large corrective steps after perturbations are mostly explained by deviations in the torso state during the previous step, suggesting that foot placement is indeed a significant stabilizing response. We also find that energy-optimal recovery transients are indeed predictive of many aspects of the human response, specifically the sideways foot placement in response to sideways perturbations, in which even simple models give quantitatively accurate results. For running, we obtained mappings from deviations in upper body state during flight and found that such deviations were predictive of the leg force impulse on the step, in a manner that state deviations were reduced, although not completely, suggesting that it takes many steps to kill a perturbation. CONCLUSIONS: Our hope is that these insights into the human walking and running control system can be used toward developing either as diagnostic metrics for quantifying stability and informing the development of control systems for prostheses and exoskeletons that work better in concert with the human walking dynamics. Supported by NSF grants 1254842 and 1538342, and a Schlumberger Foundation Faculty for the Future Fellowship. The first four authors (Joshi, Clark, Seethapathi, and Wang) contributed equally to this work and are joint first authors.

S.2. Motor Unit Control

Synchronization studies require accurate motor unit firings and robust statistical tests

Joshua Kline[1], Carlo De Luca[1]

[1]Delsys, Inc

BACKGROUND Over the past four decades, various methods have been implemented to measure synchronization of motor unit firings. Some assume the firings have a

Gaussian distribution, but never test their assumptions. Others claim synchronization indicates the motoneurons depend on common inputs without testing for statistical correlations indicative of dependent firing behavior. And almost all synchronization studies decompose the EMG signal to extract motor unit firing instances using various manual or automated methods that are subject to errors; yet the degree to which these errors distort measurements of synchronization remains a concern. In this work we show that all of these factors can result in incorrect estimates of motor unit synchronization that provide misleading physiological interpretations such as the existence of universal common inputs to all motoneurons. METHODS We developed a statistically-based method (SigMax) for computing synchronization and tested it with data from 17,736 motor unit pairs containing 1,035,225 firing instances from the First Dorsal Interosseous and Vastus Lateralis muscles - a data set an order of magnitude greater than that reported in previous studies. Motor unit firing instances were obtained using our surface EMG signal decomposition algorithms. Identification and location errors that resulted during the decomposition were evaluated and mitigated using a new error reduction algorithm designed to improve the accuracy of the decomposition result. Only firing data obtained with greater than 95% accuracy were used in the study. The data were not subjectively selected in any manner. RESULTS SigMax incorporated three distinct tests to rigorously assess the physiological incidence of synchronization: 1) test for statistically non-stationary motor unit action potential trains; 2) test for statistically dependent firing instances among pairs of motor unit action potential trains that passed the stationarity test; 3) test for the most statistically significant peak in the cross-correlation among the motor unit action potential trains that passed the dependence and stationarity tests. The synchronization peak provided the latency, peak width, and amplitude of synchronization between the motor units. Because of the size of our data set, the reduction of errors in the decomposition result and the statistical rigor inherent to SigMax the synchronization values we calculated provide an improved estimate of physiologically-driven synchronization. CONCLUSIONS When compared with other approaches used to measure synchronization, ours revealed two major findings: 1) unmitigated decomposition errors can lead to false detections and incorrect estimates of synchronization; and 2) methods that assume motoneurons depend on common inputs result in falsely ascribing synchronization to 100% of motor unit pairs studied. SigMax revealed only 50% of motor unit pairs actually manifested statistically significant synchronization.

Assessing Motor Unit Pool Control Properties in Aging using Surface Electromyography

Xiaogang Hu[1], William Rymer[2], Nina Suresh[2]

[1]University of North Carolina-Chapel Hill, [2]Rehabilitation Institute of Chicago

BACKGROUND AND AIM: A high-yield surface electromyogram (sEMG) decomposition system has been developed, which allows us to examine motor unit (MU) pool control properties noninvasively. Motor unit action potential (MUAP) shapes with corresponding motor unit threshold properties can be derived. METHODS: In this study, we first quantified the reliability of the estimated MUAP waveform features (amplitude and shape) by assessing the stability of the waveforms in relation to the accuracy of the decomposed spike timings. We then quantified the estimated action potential amplitude in relation to the recruitment threshold of motor units, obtained from the first dorsal interosseous muscle of young and elderly (50-70 age range) populations. RESULTS: Our results show that the stability (both amplitude and shape) of the waveform average was sensitive to small (i.e., standard deviation of 1 ms) spike timing errors, indicating that the estimated motor unit action potential amplitudes are reliable based on the waveform stability measures. We also found that there is orderly recruitment of motor units based on the amplitude of action potentials across different age groups. However, the strength of the orderly recruitment tends to be weaker in the elderly, especially at higher muscle contraction levels. Specifically, as shown in Figure 1, the regression slope was more shallow and the goodness-of-fit also reduced, in the elderly group. CONCLUSIONS: Our findings suggest that there is age-associated modification of the recruitment order based on motor unit size. The shallow slopes could also be a function of fiber atrophy, especially in the larger units recruited at higher thresholds.

Motor unit coherence and synchronization in response to sustained isometric contraction of the first dorsal interosseous muscle

Lara McManus[1], Xiaogang Hu[2], William Rymer[3], Nina Suresh[4], Madeleine Lowery[1]

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[1]University College Dublin, [2]University of North Carolina-Chapel Hill and North Carolina State University , [3]Northwestern University, [4]Rehabilitation Institute of Chicago

BACKGROUND AND AIM: Sustained isometric fatiguing contraction is known to induce changes in motor unit (MU) firing rate and recruitment [1]. In addition, it has been suggested that fatigue results in alterations in synchronization and correlation between the firing times of simultaneously active MUs. This is supported by indirect estimates of MU synchronization derived from surface EMG parameters [2]. Direct evidence of increased motor unit synchronization or beta-band coherence as a result of fatigue, however, has not yet been shown. The aim of this study was to examine alterations in MU coherence during and after sustained submaximal isometric fatiguing contraction of the first dorsal interosseous (FDI) muscle. METHODS: Surface EMG was recorded using a surface sensor (Delsys, Inc., Natick, MA) comprised of five 0.5 mm diameter electrodes. Data were recorded during isometric abduction of the FDI in 15 subjects (8 female) before, during and directly after sustained contraction at 30% maximum voluntary contraction (MVC) to task failure. A series of 10 s contractions at 20 % MVC were performed pre- and post-fatigue, and following 10 mins recovery. Individual MU spike trains were extracted from the surface EMG signal using the decomposition algorithm described by Nawab et al., [3] and acceptance criteria outlined in [4]. MU spike trains for each subject under each condition were divided into two groups and spike trains within each summed to yield composite spike trains. Mean squared coherence was estimated pre and post fatigue. Changes in coherence during the fatiguing contraction were similarly estimated using wavelet coherence. Short-term MU synchronization during the first and second half of the fatiguing contraction was also estimated. RESULTS: MU wavelet coherence increased in the delta (1-4 Hz), alpha (8-12 Hz) and beta (15-30 Hz) frequency bands during the fatiguing contraction, accompanied by an increase in MU synchronization($p < .001$). A significant increase in MU coherence was also observed in the delta, alpha and beta frequency bands post fatigue($p < .0001$), and recovered following rest. CONCLUSIONS: The results provide direct evidence of a fatigue-induced increase in correlated motor unit activity in the delta, alpha and beta-frequency bands. Though the origin of the coherent activity is not clear, it may reflect an increase in correlated presynaptic inputs to the motoneuron pool. Beta-band EMG coherence in particular has been shown to exhibit similar task-dependency as corticomuscular coherence,

indicating a likely cortical origin. The ability to infer information about oscillatory cortical and sub-cortical processes from surface EMG provides novel insight into the adaptations taking place in the central and peripheral nervous system during fatigue.

[1] McManus et al. J Neurophysiol, 2015. [2] Holtermann et al. J Electromyogr Kinesiol, 2009. [3] Nawab et al. Clin Neurophysiol, 2010. [4] Hu et al. J Neurophysiol, 2013.

Homogeneity of the Relationship between Motor Unit Recruitment Thresholds versus Derecruitment Thresholds across Force Levels and the Lifespan

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BACKGROUND AND AIM: During voluntary contractions, motor units are recruited and derecruited in an orderly fashion according to their recruitment thresholds. While violations to this well-ordered pattern have not been reported in young adults, it is unclear if the processes associated with aging affect the motor unit recruitment versus derecruitment threshold relationship. The purpose of this study was to examine this relationship across the lifespan and for moderate and high force levels. METHODS: Eight boys (mean ± SD age = 12 ± 2 yrs), six young men (age = 27 ± 3 yrs), and seven old men (age = 71 ± 4 yrs) participated. Subjects were free from disease, had a healthy mass, and were not engaged in an exercise program. At least 48 hours following a familiarization session, the subjects performed isometric, constant-force contractions at force levels corresponding to 50% and 80% of their maximal voluntary contraction (MVC) while bipolar surface electromyographic (EMG) signals were detected from the vastus lateralis. Force steadiness was quantified as the coefficient of variation of each plateau region. A Precision Decomposition algorithm was used to decompose the EMG signals into their motor unit action potential trains. Motor units with decomposition accuracy levels < 93.0% were removed. For each contraction, motor unit recruitment and derecruitment thresholds were quantified. Linear regression analyses were used to examine the slope coefficient (recruitment threshold % MVC/derecruitment threshold % MVC), y-intercept (recruitment threshold % MVC), and R2 of each relationship. RESULTS: Boys demonstrated the poorest force steadiness (marginal means = 3.43% [boys], 2.09% [young men], 2.12% [old men]). Each age group revealed steadier force at 50% (2.90%) versus 80% MVC (2.12%). Each age group and force level showed highly linear recruitment versus derecruitment threshold relationships (R2 >.79). Similarly, the subjects showed similar slope coefficients (mean = 1.47 %/%), with boys and young men showing greater mean values at 80% MVC compared to 50% MVC. The y-intercept demonstrated a significant main effect for force, with lower values demonstrated for 80% MVC (-30.0%) versus 50% (-4.8%). At 50% MVC, the subjects demonstrated equivalency of recruitment and derecruitment thresholds or motor units were derecruited at higher force levels than which they were recruited. At 80% MVC, a crossover effect was noted for the boys and young men, with motor units derecruited at low force levels. CONCLUSIONS: The relationship between motor unit recruitment versus derecruitment thresholds remains linear across force levels and the lifespan. While additional analyses are required to confirm our findings, older adults may recruit and derecruit motor units at similar force levels, particularly during contractions near the MVC. This phenomenon may be related to altered force-twitch potentiation or fatigability due to an age-related loss of high threshold motor units.

Transposed firing activation of motor units during oscillatory contractions

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BACKGROUND AND AIM: The majority of studies on the behavior of motor units during voluntary contractions have been performed during linearly-varying or constant force contractions. In these force paradigms, the recruitment and firing rate of motor units are organized in a strict hierarchical structure that determines their participation in the force generation process. Motor units are activated in a hierarchical order, with the earlier-recruited motor units being activated at lower forces and exhibiting greater firing rates than the later-recruited ones [1]. We performed this study to investigate whether this hierarchical firing rate organization of motor units can be altered during isometric oscillatory-force contractions. METHODS: Six healthy young (23.8 ± 2.0 yr) subjects were asked to track a target

force profile at 20% of their maximal voluntary contraction (MVC) force with a superimposed oscillation of amplitude ±2.5% MVC and frequency increasing from 0.2 to 0.4, 1, 2, 3, and 4 Hz. The first dorsal interosseous muscle was tested while the hand was secured to restrain the index finger to isometric contractions. RESULTS: We found that the normal pattern of activation observed during linearly-varying or constant force contractions can be altered by performing oscillatory contractions at frequencies ≥ 2 Hz. We identified the following surprising alterations in the firing behavior of motor units with increasing oscillation frequency: 1) the firing rates of lower-threshold motor units decreased when the force began to oscillate, and returned to their pre-oscillation level when the oscillation terminated; 2) the firing rate decrease was progressively less pronounced for higher-threshold motor units; 3) the firing rate decrease was progressively more pronounced at greater oscillation frequencies; and 4) additional higher-threshold motor units were recruited when the decrease in the firing rate of the lower-threshold motor units was noted. CONCLUSIONS: Our results demonstrate that the hierarchical regulation of motor unit firing can be manipulated to preferentially activate specific motoneuron populations, providing an opportunistic access to increasing the activation requirement of higher-threshold motor units while decreasing that of lower-threshold ones. This finding can be exploited to develop new forms of physical therapies and exercise programs that enhance muscle performance or that target the preferential atrophy of high-threshold motor units that occurs with aging or motor disorders such as stroke and amyotrophic lateral sclerosis. [1] De Luca CJ et al. J Physiol, 329: 129-142, 1982. Support: NIH/NICHD Grant HD-050111; Neuromuscular Research Foundation.

Biomechanical Benefits of the Onion-Skin Scheme of Motor Unit Firing

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BACKGROUND AND AIM: Muscle force is modulated by varying the number of active motor units and their firing rates. Over the past five decades, the notion that higher-threshold shorter-after-hyperpolarization (AHP) motoneurons have greater firing rates than lower-threshold longer-AHP ones has been commonly accepted. This notion was derived from electrically stimulated motoneurons in cats, and supports

the assumption that the firing rates of motoneurons match their mechanical properties to optimize force generation [1]. That is, lower-threshold motor units have wider and smaller force twitches that require lower firing rates to tetanize. In contrast, we have provided evidence that earlier-recruited motor units maintain higher firing rates than later-recruited ones at any time and force during voluntary isometric contractions, resulting in an inverse orderly hierarchy of firing rate curves named the Onion-Skin scheme [2]. We applied a model of muscle force generation [3] to compare the force characteristics produced by the APH and the Onion-Skin schemes in the First Dorsal Interosseous (FDI) and Vastus Lateralis (VL) muscles. METHODS: The model describes a hierarchical inverse relationship between the recruitment threshold and the firing rate of motor units at any time and force during a voluntary contraction to formulate the Onion-Skin scheme. An opposite arrangement where both the minimal and maximal firing rates of motor units are directly related to recruitment threshold formulates the AHP scheme. RESULTS: Our results show that the Onion-Skin scheme has distinct advantages over the AHP scheme: 1) lower-threshold motor units fire faster and produce more force at low levels. Thus, a fewer number of low-threshold units, in most part oxidative and able to sustain force for extended time, are required for low force production. 2) High-threshold motor units never fully fuse, maintaining the potential for a force "reserve capacity" that is not normally accessible but might be available in extraordinary circumstances. 3) It produces smoother force, especially at the low force levels that are used for normal daily activities. 4) It provides more sustainable contractions by producing lower forces at maximal excitation. CONCLUSIONS: In summary, the Onion-Skin scheme is not designed to maximize muscle force, as proposed for the AHP scheme, but to generate force more quickly when force is initiated, and to provide lower maximal force with the capacity to sustain it over longer time. Smoother force production also enables accurate performance of daily tasks. These features support the flight-or-fight reflexive response in the presence of danger and are more conducive to evolutionary survival. [1] Eccles et al. J Physiol, 142: 275-291, 1958. [2] De Luca et al. J Physiol, 329: 129-142, 1982. [3] Contessa and De Luca. J Neurophysiol, 109: 1548-1570, 2013. Support: NCMRR/NICHD Grant HD-050111; Neuromuscular Research Foundation.

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O.1. Rehabilitation Technologies I

O.1.1 *A new wearable exoskeleton device that controls knee motion in individuals after stroke*

Shihomi Kawasaki[1], Koji Ohata[1], Tadao Tsuboyama[1], Yuichi Sawada[2], Yoshiyuki Higashi[2]

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BACKGROUND AND AIM: Abnormal knee movement patterns were reported as common characteristics of gait abnormality in individuals after stroke. Previous reports have selected knee movement during walking as a critical observational point for gait pattern classification. (De.Quervain IAK, 1996, Mulroy S. 2003). Moreover, the reduction of knee flexion during swing phase was known as a factor increasing mechanical energetic costs (Chen G, 2005). Thus, improving abnormal knee movement is necessary to recover the gait function in this population. Recently, robot rehabilitation is expected to facilitate training for individuals after stroke. However, many of the robots have to be combined with treadmills and wearable robots for overground use are not popular yet in clinical settings. We developed a device that assists knee movements during gait and can be used overground. The aim of this study was to clarify the change of knee motion using the device.
METHODS: Three subjects with left hemiplegia after stroke with an average age of 43.7y (SD 22.5y) participated in this study (male/female: 2/1, Brunnstrom Recovery Stage IV/V: 1/2). They walked with the new device to control the knee movement during gait with an attached actuator at the knee joint. This actuator was controlled to assist the knee motion in appropriate timing and power, using a programmed algorithm corresponding to their gait cycle. The subjects walked at their own preferred speed on a 7-meter walkway in two conditions: with no assist or with a 6N assist on the paretic knee. The knee joint angle during gait was measured by an electric goniometer attached to the paretic knee. The maximum knee flexion angle during swing, knee flexion angles during loading response and knee extension angles during mid-stance were compared between the 2 conditions. Temporal information of the gait was obtained from an accelerator on the paretic heel.
RESULTS: With the assist, all subjects increased the maximum knee flexion angle

during swing (31.3 to 35, 32.4 to 44.3, 29.3 to 33.4 degrees in knee flexion). In loading response, two subjects with normal knee motion during stance showed reduced knee flexion (21.7 to 17.3, 15.3 to 9.8 degrees in knee flexion). On the other hand, one subject with recurvatum-knee motion during stance decreased the peak knee extension angle (-2.6 to 4.2 degree in knee flexion). However, changes in gait speed and gait cycle proportion were inconsistent. CONCLUSION: This preliminary study supported the hypothesis that this new device improves the knee motion in hemiplegic gait. The device probably has a potential to change the common problem such as stiff knee gait and recurvatum knee gait. Future study is needed to examine the effect of this device and to optimize the algorithm for the improvement of the gait function in individuals with hemiplegia after stroke.

O.1.2 ***A Novel Device for Functional Strength Training during Gait: Evidence from Healthy and Stroke Subjects***

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[1]University of Michigan

BACKGROUND AND AIM: Many patients with neurological injury such as stroke or cerebral palsy have significant limitations in walking, which can affect their mobility and quality of living. Facilitating gait recovery, therefore, is a key goal in rehabilitation. Task specific training is frequently applied for rehabilitation of these individuals, but this fails to directly address muscle strength and impairment, which are also critical for motor recovery. For this reason, functional strength training — task-specific loading of the limbs — is becoming increasingly popular when rehabilitating these patient groups. Typically, the resistance necessary for functional strength training of gait is provided using cable robots or weights that are secured to the distal shank of the subject. However, there exists no device that is wearable and capable of providing resistance across the joint, allowing over ground gait training. Therefore, the goal of this study was to develop a gait-training device that is capable of providing variable levels of resistance across the knee during walking and to test the biomechanical effects of this device on the user. METHODS: We first created a benchtop viscous damping device in the form of an eddy current disc brake, and characterized its resistive torque profile using an isokinetic dynamometer. After characterizing the resistive properties of the device, we tuned the parameters

(magnet size, number, etc.) to optimize wearability while maintaining a high resistance. The device was then fitted to an orthopedic knee brace (T Scope Premier Post-Op Knee Brace, Breg, Grand Prairie, TX) that can fit across a wide range of patient sizes (5' to 6'7").The entire assembly weighed 1.6 kg and cost about $2100 for fabrication (including the brace). We then validated the device by having subjects (healthy and stroke) wear it during a walking task through varying resistance levels. Electromyography and kinematics were collected to assess the biomechanical effects of the device on the wearer. RESULTS: Results from benchtop testing indicated that eddy current braking provided resistance levels suitable for functional strength training of leg muscles in a package that is both lightweight and wearable. Human subjects experiment indicated that applying resistive forces at the knee joint during gait resulted in significant increases in muscle activation of many of the muscles tested. A brief period of training also resulted in significant aftereffects once the resistance was removed. Additionally, preliminary results gathered while testing on stroke subjects showed similar changes in muscle activation and substantial aftereffects that translated to their over-ground walking. CONCLUSION: These results support the feasibility of the device for functional strength training during gait. However, future research is warranted before the device is applied in the rehabilitation setting. ACKNOWLEDGEMENT: NIH Grant#R01EB019834

O.1.3 ***Gait Rehabilitation in Paediatric Population through a Novel Robotic Platform: Pilot study***

Cristina Baruón[1], Eduardo Rocon[1]

[1]CSIC

BACKGROUND AND AIM: Cerebral Palsy (CP) is a disorder of posture and movement due to a defect or lesion in the immature brain. New strategies are needed to help to promote, maintain, and rehabilitate the functional capacity, and thereby, diminish the dedication and assistance required and the economical demands that this condition represents for the patient, the caregivers and the society. This study presents the development and preliminary clinical evaluation of a new robotic platform called CPWalker for gait rehabilitation and training in patients with CP, and its applicability with CP children. METHODS: CPWalker is a robotic platform that allows the infant to start experiencing autonomous locomotion in a rehabilitation environment. This robotic platform consists of a smart walker with body weight support and a wearable exoskeleton robot for joint range of motion support. CPWalker control strategies provide the infant with a force field to rehabilitate his/her gait to physiological patterns. The device was evaluated in three children with spastic diplegia aged between 12 and 14-years-old. These children went through the individual robotic-based rehabilitation programme during five weeks. For the outcome measures, 3D motion capture system was used to calculate kinematics and kinetics parameters in pre and post studies (before and after the experiment period respectively). RESULTS: After five weeks of robot-based training with CPWalker system, the three children improved the mean velocity, cadence and step length after robotic-based therapy (Table I). Post studies revealed that the trajectories for right and left lower limbs are closer to the normal values when compared with pre studies (Figure 1). CONCLUSIONS: Preliminary results show the potential of the novel robotic platform to serve as a rehabilitation tool. CPWalker enables overground training of walking with controlled body-weight support in children with Cerebral Palsy. The ability to provide autonomous locomotion to the children improved their participation during the therapy, with positive effects. The system is robust and safe for the children. Such device is a powerful tool to evaluate and compare different robotic-based therapies for gait rehabilitation of children with CP. [1] Bayón et al. CPWalker: Robotic Platform for Gait Rehabilitation in Patients with Cerebral Palsy. IEEE Int. Conf. Robot. Autom., 2016. doi:10.1007/s13398-014-0173-7.2.

O.1.4 ***The kinematic change for inverted pendulum during stance phase with assist of hip movement in individuals after stroke.***

Koji Ohata[1], Shihomi Kawasaki[1], Yasushi Ikeuchi[2], Yosuke Nagata[2], Toru Takenaka[2]

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Background: The inverted pendulum model during stance phase is crucial principle to reduce the energy cost during walking in human (Kuo, 2007). This model can explain the conservation of mechanical energy of walking due to effective exchange between kinetic and potential energies. Hemiplegic gait was previously reported to perform inadequate way to exchange between energies (Olney, 1986) and to need high energy cost during walking (Waters, 1999). The assist of hip movement using wearable actuator generated supportive power to the thigh during walking has

potential to be useful as one of the assist technology in robot assisted gait training (RAGT). Previous study has reported that the device controlling the thigh movement improved cost of walking (Kitatani, 2014) and symmetry (Buesing 2015). However, kinematic parameters that indicated the change in movement of the inverted pendulum were not investigated. Aim: The aim of this study was to clarify the kinematic change concerned with inverted pendulum model by controlling the hip movement in individuals after stroke. Methods. 17 ambulatory individuals after stroke participated in the study. They walked with assist of hip movement using the device attached actuators on 7m-walkway at self-selected speed in two conditions, i.e., turn-on and turn-off the actuator of the device conditions. Gait kinematics was assessed using 3D gait analysis (MAC3Dsystem, USA). Gait trials on each condition were performed 4-6 times. 5 or more gait cycles were used to calculate parameters in analysis. A gait parameter concerned with inverted pendulum (IP) was defined as the rotation angle of a line connecting between center of ankle joint and the center of gravity (COG) during the single stance phase. Moreover, general gait parameters such as gait speed, stride and step length, cadence, gait temporal and spatial asymmetry were measured. The relationships between IP and various parameters were tested using Pearson correlation coefficient and the changes with hip assist were examined using paired t-test ($p<0.05$). Results: IPs on both sides showed highly positive correlations with gait speed, stride, and step length and negative correlations with spatial asymmetry. The assist of hip significantly increased IP on non-paretic side and significantly reduced temporal asymmetry. Improvements in gait speed and stride length with the assist showed significant positive correlation with increase of IPs on both sides. Change of temporal asymmetry also significantly correlated with changes of IPs on both sides. Conclusion: The results of this study suggested that IPs on both side were essential parameters of gait function in hemiplegic gait. The assist of hip movement using actuators improved the IP on non-paretic side with reducing their asymmetry. However, general gait parameters did not change perhaps of limited change in IP on paretic side.

O.1.5 *Measuring balance control on a treadmill: no need for shear forces*

Ingrid Schut[1], Jolanda Roelofs[2], Jantsje Pasma[1], Herman van der Kooij[1], Vivian Weerdesteyn[2], Alfred Schouten[1]

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BACKGROUND AND AIMS People who sustained a stroke often undergo impaired balance. To give insight into the neurophysiological mechanisms underlying impaired balance, system identification techniques in combination with perturbations can be used in which the body is perturbed using motion platforms. However, a motion platform is a dedicated and large device, which is unavailable in most labs and clinics. Treadmills are becoming more popular and affordable and are used to train gait in neurological patients. This study investigates the possibilities of measuring balance control using a treadmill and what the minimal set of signals might be. Therefore, we first investigate which forces and moments are necessary to identify the neurophysiological mechanisms. METHODS In this study, 2 healthy women (age 20-30 years) were asked to maintain their balance while standing on a dual force plate treadmill (GRAIL), while the belt speed was perturbed in both directions around an equilibrium position. A multisine perturbation containing frequencies in the range of 0.05-5 Hz was applied on the belt resulting in peak-to-peak translations of 23 cm with a duration of 20 seconds. Three trials consisted each of 5 repetitions of the perturbations signal, resulting in three trials of 100 seconds. Horizontal and vertical ground reaction forces (i.e. shear forces and gravitational forces) were measured to calculate the corrective ankle torque consisting of the shear force induced torque component and the gravitational force induced torque component respectively. Body kinematics were measured using a motion capture system to calculate the body sway. Corrective ankle torque and body sway were used for system identification techniques to calculate the frequency response function (FRF) of the neuromuscular controller. To investigate the contribution of the shear forces on the FRF, the corrective ankle torque was calculated both with and without incorporating the shear forces. The mean of the difference in torque was calculated in percentage and the difference in magnitude of the resulting FRF was calculated for all frequencies in percentage. RESULTS Preliminary results show that the mean difference in torque calculated with and without shear forces is between 0.01-9% for all subjects. All subjects show that the variation in FRFs between repeated trials is larger than the variation in FRFs calculated with and without shear forces (averaged standard deviations of 0.24 and 0.04 respectively). The difference in FRF increases as the frequency increases and does not exceed 5%. CONCLUSION This study shows that the shear force induced torque component is negligible to the ankle torque during stance on a treadmill and could be ignored for simplifying measurements of balance control. The calculated FRFs are comparable with previous studies, in which motion platforms were used. This is a promising result for system identification techniques on treadmills to measure balance control.

O.1.6 *The Effect that Joint Mobilization has on Propriospinal Reflexes and Pain*

John McLinden[1]

[1]University of Rhode Island

INTRODUCTION: Individuals diagnosed with chronic pain (ChPa) display a range of unexpected neurologic and muscular changes. Patients report lower pain thresholds and display heightened flexor withdrawal responses. Despite evidence for more widespread changes, the current consensus is that ChPa conditions are manifestations of central hypersensitization. The finding that joint mobilizations (JM) diminishes the flexor withdrawal reflex supports the hypothesis that proprioceptive information may also influence central pathways. To our knowledge no studies have looked at the effect that JM has on spinal proprioceptive reflexes and descending neural drive in people with ChPa. This study therefore investigated the effect that JM has on the H-reflex and the V wave in people with ChPa. METHODS: Thirty subjects (18-65 years-old) experiencing ChPa at or below the knee volunteered for this study. ChPa was defined as pain that has been present for at least six months that was not attributable to any physical trauma or pathology. People with osteoarthritis of the knee or ankle were also included. The experimental protocol was a two group, random selection, Pre-test, Post-test design where reflex recordings were taken before and after a treatment intervention to the ankle. Subjects were randomly subdivided into a treatment (txG) and a sham group (SG). The txG received JM while the SG did not. H-reflexes and V waves were elicited by stimulating the skin directly over the tibial nerve unifocally with a 1ms rectangular pulse at a frequency of 0.1 Hz. The myoelectric signal was band pass filtered at 10-10,000 Hz, digitized at 5,000 Hz and displayed and analyzed on a computer screen. The experiment began by taking pain measurements (1-10 on a 10 point visual analog scale for resting pain, and a second score for pressure pain threshold) and recording 10 H-reflexes and V-waves. These values served as baseline values with which all other recordings were compared. Subjects then received either JM or sham treatments. JM consisted of large amplitude, posterior-to-anterior direction movements to the talocrual joint at a rate of approximately 45 oscillations/minute. The sham intervention was similar to the JM setup in every way except that no talocrual joint posterior-to-anterior displacement took place. Treatments lasted for six minutes. Immediately after joint/sham mobilizations the experimental procedure was repeated. RESULTS: A 2x4 repeated measures ANOVA showed no significant difference between or within the two treatment groups for either reflex and/or pain measurements. CONCLUSION: Talocrual JM did not affect lower limb proprioceptive spinal reflexes or on the descending neural drive converging onto motoneurons. In addition, talocrual JM did not have a generalized effect in lowering pain levels. This finding suggests that JM may be only useful in decreasing pain levels specifically to the joint being mobilized.

O.2. Neuromechanics I

O.2.1 *Task dependancy in Sensorimotor Training: Influence of free bipedal and unipedal stance on variance of soleus H-reflex amplitudes*

Gunnar Wahmkow[1], Tilman Engel[1], Steffen Müller[1], Eduardo Martinez-Valdez[1], Kaplick Hannes[1], Frank Mayer[1]

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BACKGROUND AND AIM: Sensorimotor training was shown to be effective for postural control and improved balance in rehabilitation and prevention. The H-reflex is often used to identify spinal adaptation after sensorimotor training. Recruitment curves are commonly evaluated in prone position or fixed bipedal stance, to either serve as a direct outcome for adaptation after intervention through the Hmax/Mmax -ratio or as orientation for stimulus intensities during other measurement tasks. As adaptational effects of sensorimotor training on H-reflexes were shown to be highly task specific, conditions during H-reflex assessments should match sensorimotor training demands. Therefore, the purpose of this study was to assess H-reflex amplitudes and their variance in free bipedal compared to unipedal stance. METHODS: 14 healthy subjects (8f/6m, 171±8cm, 65±12kg, 29±2yrs) performed free bipedal and unipedal stance in a randomized order on a force plate (AMTI Netforce). Subjects were advised to stand as still as possible with their hands on the pelvis and

viewing straight forward. After COP was measured 3x25s in bipedal and unipedal stance, a recruitment curve of M-Wave and H-reflex was recorded from the soleus muscle for both conditions. Afterwards another 10 stimuli per condition were applied with an individual consistent current at Hmax from the assessed recruitment curve. Statistical analysis was performed with a one way ANOVA (α=0.05) of means for COP path length [mm], Hmax/Mmax -ratio and the coefficient of variation [%] of 10 stimuli at Hmax from the recruitment curve. RESULTS: Findings showed a significant increase of postural sway from bipedal (241±63mm) to unipedal (856±263mm) stance (p<0,05) in all subjects. No significant differences between bipedal (0.52±0.32) to unipedal (0.54±0.32) stance (p>0,05) were found for the values of the Hmax/Mmax -ratio. The coefficient of variation in Hmax amplitudes was significantly lower in unipedal (20±14%) than in bipedal (57±24%) stance (p<0,05). CONCUSIONS: Unipedal stance is a common position for functional tasks in sensorimotor training. It increases limb loading as well as task difficulty as shown by differences in COP displacement compared to bipedal stance. However, unchanged Hmax/Mmax -ratio suggest that differences in task difficulty between bipedal and unipedal stance are not strong enough to provoke alterations in reflex modulation at the spinal level. Nevertheless, the lower variation of Hmax reflex amplitudes in unipedal stance suggests that a more unstable task with higher COP displacement does not lead to more variation of Hmax reflex amplitudes. The findings of the present study indicate a great usefulness for more training related measurement tasks in the assessment of task specific adaptations via H -reflex method.

O.2.2 *Trunk Muscle Reflexes Are Elicited by Small Continuous Perturbations*

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BACKGROUND AND AIM: Low-back pain (LBP) has been recognized as the leading cause of disability worldwide. Lumbar instability has been considered as an important mechanism of LBP and one potential contributor to lumbar stability is trunk muscle reflex activity. Indeed, it has been shown that some LBP sufferers display delayed reflex responses. However, it remains unclear as to what extent this reflex pathway contributes to overall lumbar stability. Numerous studies have quantified the

mechanical stiffness of the trunk as a surrogate measure for lumbar stability. However, these studies use continuous small stochastic perturbations to quantify lumbar stiffness, whereas reflexes are commonly elicited using single large perturbations. Thus, it remains unknown whether reflexes are elicited in the studies that use small continuous perturbations to quantify lumbar stiffness, and hence, whether these paradigms could properly quantify the reflex contribution to overall lumbar stiffness. In this study, we determined to what extent reflexes of various trunk muscles were elicited by the small continuous perturbations normally used to quantify the lumbar stiffness. METHODS: Thirty six subjects, 19 with no history of LBP, and 17 suffering from chronic LBP stood upright with their chests' attached to a linear motor via an adjustable harness at the T8 level while perturbations, which consisted of a 4 mm pseudo-random binary sequence (PRBS) with a switching rate of 150 ms, were applied. Electromyographic (EMG) activity was measured from 3 trunk extensor muscles-longissimus (LO), illiocostalis (IL) and multifidus (MF)-and 3 trunk flexor muscles-rectus abdominus (RA), internal oblique (IO) and external oblique (EO). EMG activity in response to each perturbation was separated based on the direction of the perturbation (i.e. forward or backward), aligned and averaged. Reflex activity for each direction was computed as the mean rectified EMG activity at four times: 25-50 ms (M1), 50-75 ms (M2), 75-100 ms (M3) and 100-125 ms (long-latency reflex-LLR) following the perturbation. RESULTS: The small continuous perturbations were capable of eliciting reflexes, as reflex activity was seen in all muscles. 34 of the 48 muscle-epoch combination showed a significant reflex response to either perturbations in the forward or backward direction. Though it is impossible to classify one muscle as having the largest reflex responses, 4 muscle-epoch combinations (M1 & M2 in IL, M1 in IO and LLR in EO) were larger than the rest. Though not the primary objective of this experiment, we found no group differences between healthy and LBP populations. There were group differences between males and females, as males tended to have larger short latency reflex responses, while females had larger LLR responses. CONCLUSION: Reflexes are elicited by small continuous perturbations, and should contribute to the measured mechanical lumbar stiffness by this and similar type of experiments.

O.2.3 *Heteronymous models are needed to describe shoulder stretch reflexes*

M. Hongchul Sohn[1], Emma Baillargeon[1], David Lipps[2], Eric Perreault[3]

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BACKGROUND AND AIM: Healthy shoulder function requires the humeral head to remain secure in the glenoid cavity. Stretch-sensitive feedback may be critical for glenohumeral stability, and it is known that pathologies impairing feedback (e.g. stroke or spinal cord injury) often lead to severe shoulder insta-bilities. However, little is known about stretch reflexes at the shoulder due to challenges with measuring them reliably. We developed a manipulandum to study 3D shoulder mechanics, and the underlying neural control. This study investigated the coordination of stretch reflexes elicited by rotations of the gleno-humeral joint, as a step towards understanding their role in maintaining shoulder integrity. We hypothe-sized a heteronymous organization whereby shoulder reflexes in any muscle would be sensitive to the background activity of multiple muscles crossing the shoulder. METHODS: We recorded electromyograms (EMGs) from 8 shoulder muscles in response to random dis-placements in 6 directions spanning the degrees of freedom of the glenohumeral joint. Reflexes were quantified by average rectified EMG in short- (20~50 ms), medium- (50~75 ms), and long-latency win-dows (75~100 ms) after perturbation onset; background activity was computed -100~0 ms before each perturbation. Reflexes were elicited as subjects (n=11) generated isometric torques (10 or 20% maximum contraction) in the 6 measurement directions, and when relaxed. These volitional torques created rich pat-terns of background activity, providing a means to test our hypothesis. This was done using a linear mixed-effects model between the background activity of all muscles and the stretch reflexes elicited in each muscle. Separate models (n=144) were constructed for the reflexes in each muscle, each perturbation direction, and each response window. A simulated log-likelihood ratio was used to determine if models considering background activity in all muscles (heteronymous) were significantly better than those con-sidering only background activity in the muscle in which the reflex was measured, reflecting a homony-mous organization. RESULTS: The heteronymous model was significantly better than the homonymous model for 96% of the tested conditions. These results did not differ across measurement windows (p=0.16). The magnitude of the improvement was generally greatest for the largest reflex responses, which typically resulted from perturbation directions that caused the largest change in muscle length. For these conditions, the heteron-ymous models had an average R^2 = 0.63

± 0.18, and explained 18 ± 15% more of the total measured variance than the homonymous models, demonstrating a wide range of improvements.
CONCLUSIONS: Our results demonstrated clear and strong stretch reflexes in muscles crossing the glenohumeral joint. The vast majority of these reflexes were explained best by a heteronymous model in which the response in any one muscle was modulated by the background activity in multiple muscles.

O.2.4 *Nonlinear connectivity in the human stretch reflex revealed by nonlinear phase coherence and multisine perturbations*

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ACKGROUND AND AIM: Reflexes are fast involuntary motor reactions with various latencies in response to unexpected perturbations. A common way to investigate reflexive behavior is to use mechanical perturbations (Kearney & Hunter, 1989). Previous studies used multisine perturbations (sums of sinusoids) for system identification of the human reflex system involving muscle spindles, Golgi tendon organs, the spinal cord and supraspinal systems (Abbink et al, 2011; Schouten et al, 2008). These studies mainly assessed linear input-output relations in human stretch reflexes, though several basic elements in the nervous system, such as muscle spindles, have been shown to be highly nonlinear (Gielen & Houk, 1987). This study explores nonlinear connectivity in the human stretch reflex using multisine perturbations and our recently developed nonlinear measure, namely multi-spectral phase coherence (MSPC) (Yang et al, 2016). MSPC is a nonparametric nonlinear phase coherence measure capable of assessing nonlinear input-output interactions and time delays in the nervous system. Since the multisine perturbation contains only a limited number of frequency components (fi, i = 1, ..., N), nonlinear connectivity can be detected by calculating nonlinear coherence between the stimulation frequencies and their harmonic (k*fi) and intermodulation frequencies (sum(ki*fi)) in the EMG.
METHODS: Eleven subjects exerted an isotonic wrist flexion (1 Nm) while a manipulator imposed a multisine position perturbation to the same wrist. The multisine signal consisted of the sum of three sinusoids (7, 13 and 29 Hz, period: 1s, 1320 periods in total) with random phases. These frequencies allow for the

assessment of all second and third order nonlinearities without overlap in the output spectrum. Differential EMG signals were recorded from the flexor carpi radialis and the extensor carpi radialis muscles. The EMGs were digitally filtered by high-pass (35 Hz) and notch (50 Hz) filters to remove movement artefacts. Afterwards, the EMGs were full-wave rectified. We computed the nonlinear connectivity and time delay from the perturbation to EMG using MSPC. RESULTS: Nonlinear connectivity from the perturbation to EMG signals was detected in both second and third order harmonics and intermodulations of the stimulation frequencies. The estimated time delay from the multisine perturbation to EMG was 33 ± 6 ms, in accordance with the reported latency of the spinal stretch reflex at distal arm muscles to transient perturbations (Gorden et al, 2000). CONCLUSIONS: This study provides new evidence of nonlinear neuronal connectivity of the stretch reflex, in terms of nonlinear phase coherence. The estimated time delay indicates a major contribution of the spinal reflex loop to the nonlinear connectivity, in comparison with the transcortical component of the reflex which would result in longer delay. Our approach provides a useful tool to study nonlinear connectivity in the reflex system.

O.2.5 *Peri-patellar taps elicit regional stretch reflexes in the human vastus medialis*

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BACKGROUND AND AIM: Due to regional variations in fiber orientation and broad attachments, many human muscles have the potential to produce forces along different directions. The activation of these muscle regions may be regulated regionally based on local feedback from muscle spindles (Windhorst et al, 1989). While experiments with animal models provided some evidence for the regionalization of stretch reflexes (Cohen, 1953), experiments on the human tibialis anterior did not reveal such regionalization (McKeon et al, 1984). Because of its anatomy, the tibialis anterior has low potential for producing force in different directions; for this reason, we have investigated the regionalization of stretch reflexes in a human muscle with known region-specific directions of force production: the vastus medialis (VM). METHODS: Nine healthy individuals participated in this study. Using a custom-made hammer with an embedded load cell, taps were applied manually in steps of 10 mm to multiple regions along the VM insertion on the patellar edge. Thirty taps with varying intensity were applied to each location. A high-density surface EMG grid (5 columns by 13 rows spaced 8 mm) was placed across the VM, proximally to the innervation zone. In 3 participants, intramuscular recording electrodes were also inserted in 3 regions of the VM under the electrode grid. For the surface EMG, only trials where action potential propagation could be observed were included in the analyses. To standardize the input force applied across locations, 5 taps with comparable peak force were selected for each location. For each channel, the amplitude of the response was calculated as the magnitude of the largest negative peak occurring 15-45 ms after the tap. The amplitude distribution of the EMG response across the muscle was calculated by averaging the amplitude values for each row, resulting in an array of 13 amplitude values that formed a cross-section of the VM. The barycenter of the channels with amplitude larger than 70% of the peak of the distribution was used to describe the location of the response across the grid. RESULTS: Taps applied with similar input force (coefficient of variation: 3.42 ± 1.85%) resulted in localized, discrete responses of the stretched fibers only (3-5 regions for each participant). The location of the elicited responses was dependent on the location of the tap (ANOVA, $P < 0.001$; figure). Recordings with intramuscular electrodes confirmed the regional activation of the VM at different tap locations. CONCLUSIONS: These results indicate that motor neurons innervating fibers located in different muscle regions may be independently activated at the spinal level. As VM motor units located in different muscle regions have potential for producing force along different directions (Gallina and Vieira, 2015), these results suggest that these motor units can be recruited, at the spinal level, based on the mechanical efficiency of their muscle fibers.

O.2.6 *Evidence of Invariance in the Lower Leg Muscle?s Response due to Stretch Reflex Excitation during Movement.*

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Joint dynamic stiffness defines the relation between joint position and torque and dictates the joint response to unexpected perturbations. At the ankle, it is composed by the intrinsic, given by the viscoelastic and inertia properties of the joint, connective tissue and muscle, and the reflex component, given by the involuntary muscle activation due to the excitation of the stretch reflex mechanism. These two components act and change together so that estimating their relative contribution to the joint stiffness is a challenging problem. Several methods have been proposed for this task, among those, an analytical method that describes the joint dynamic stiffness by a parallel cascade structure where the intrinsic and reflex stiffness are given by a linear system and a series connection of a delay, a differentiator, a static nonlinearity and a linear system respectively, and estimates the system parameters from joint position and torque records, has been successfully used in our laboratory to separate the joint dynamic stiffness components. Using this method, it has been shown that joint stiffness model parameters change significantly with discrete changes in the joint position and torque (operating point). Recently, we extended this technique to estimate the joint dynamic stiffness during continuous changes in the operating point. This new method assumes that the parameters of the model are time-varying (TV) and can be described as linear combinations of predefined basis functions. An experimental study that involved an imposed ramp-and-hold movement with constant muscle activation showed that the novel joint stiffness model and identification algorithm were able to appropriately describe the intrinsic and reflex component during movement. It was observed that all the elements of the intrinsic stiffness changed significantly as a function of the joint position. Conversely, only the static nonlinearity in the reflex pathway showed significant changes with as the joint position changed. However, as the stretch reflex system, composed by the muscle spindles, neural connections and muscles, is lumped in a single non-linear system in our model, is difficult to dissect the response of each individual element. The stretch reflex response can also be modelled as the relation between rectified reflex EMG and torque. This relation bypasses the muscle spindle and neural connections, modelling only the relation between the electrical activity at the muscle and the produced torque. Provided this, we modified our algorithm to estimate the relation between joint position, reflex EMG and torque as a MISO, linear, TV system. Experimental results showed that the system representing the reflex EMG-torque does not change as function of the joint position. This indicates that the muscle?s response to the stretch reflex activation is invariant during the movement, and so, the source of the reflex modulation should be located in another component of the system

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O.3. EMG: modeling

O.3.1 *Comparison of EMG Feature Projection Techniques for Force Estimation*

Muhammad Asim Waris[1], Winnie Jensen[1], Kevin Englehart[2], Ernest Kamavuako[1]

[1]Aalborg University, [2]University of New Brunswick

BACKGROUND AND AIM: In a process of extracting useful and meaningful information from the electromyogram (EMG) signal, feature reduction is considered as a valuable processing step to remove redundancy in the future space. This study investigates the effect of seven feature projection techniques on the estimation of force from EMG signals. METHODS. In this study we used previously recorded data during single and combined movements; see Kamavuako et al. (2013) for more details about the experimental protocol. From the six surface EMG channels, 11 time and frequency domain features (variance, mean absolute value, modified absolute value, mean absolute value slope, root mean square, Wilson amplitude, zero crossings, slope sign change, waveform length, mean frequency and mean power) were extracted from overlapping (by 50 ms) windows of 200 ms. We compared the following techniques: locality preserving projections (LPP), linear graph embedding (LGE), principal components analysis (PCA), orthogonal locality preserving projections (OLPP), isometric projections (IsoP), neighborhood preserving projections (NPE), uncorrelated linear discriminant analysis (ULDA) and orthogonal linear graph embedding (OLGE) at different number of retained features. The association between the reduced features and force was investigated using a linear regression model, with the coefficient of determination R^2 as performance measure. RESULTS: The coefficient of determination without any dimensionality reduction analysis (0.76±0.20) was used as the baseline, and compared to projection techniques where the turning point before the plateau was quantified. Performance was: LGE (0.87±0.20), LPP (0.86±0.33), PCA (0.78±0.19), NPE (0.85±0.20), OLPP (0.76±0.18), OLGE (0.77±0.21), ULDA (0.83±0.23) and IsoP (0.81±.22) averaged across all subjects. Performance measure approached maximum at the following reduced dimensions: LPP (8), LGE (6), PCA (18), ULDA (23), NPE (10), IsoP (12), OLGE (24) and OLPP (20).

IsoP was the most computationally complex technique. CONCLUSION: Results showed that in case of high dimensionality, LGE and LPP could improve performance and may be used as an alternative to PCA based techniques. REFERENCE: Kamavuako EN, Scheme EJ, Englehart KB. J Neurophysiol. 2013, 109(11):2658-65.

O.3.2 *Periods of non-stationarity indicate motor unit recruitment in the tibialis anterior muscle of young healthy adults*

Shanette Go[1], William Litchy[1], Carlos Mantilla[1], Gary Sieck[1], Kenton Kaufman[1]

[1]Mayo Clinic

BACKGROUND AND AIM: The orderly recruitment of motor units according to the Henneman size principle allows for efficient force generation. Recent studies have shown that periods of non-stationarity in the rat diaphragm electromyography (EMG) signal during ventilatory and non-ventilatory behaviors correspond with motor unit recruitment (Seven, et al. 2013). Furthermore, this non-stationary period was shorter during activities that required higher force production rates (e.g. sneezing) compared to activities that required lower force production rates (e.g. eupnea), indicating greater central drive. The specific aim of this study was to investigate the non-stationarity in surface EMG signals collected from the human tibialis anterior (TA) muscle during ramped isometric contractions. We hypothesized that higher rates of force generation would result in a shorter non-stationary period compared to lower rates of force generation. We also hypothesized that higher force generation rates would have a right shifted frequency spectrum compared to lower force generation rates, indicating the recruitment of fast-twitch motor units. METHODS: Eight young healthy adults (5 males; 26±2 years old; BMI: 22±2 kg/m^2) participated in this study. A bipolar stainless steel surface electrode was placed over the right TA muscle belly parallel to the muscle fibers. Ankle dorsiflexion force and surface EMG were simultaneously acquired at 2500 Hz per channel as subjects performed ramped isometric contractions at rates of 5%, 10% and 15% of each subject's maximum voluntary contraction (MVC) per second. Each force rate was repeated fifteen times. The stationarity of each signal was assessed in 20 ms segments over a 360 ms moving average window using the reverse arrangement test. Power spectral analysis was performed on stationary segments and the median power frequency (MedPF)

was calculated. A repeated-measure mixed model was used to test for differences, and Tukey-Kramer post-hoc analyses were used when appropriate ($\alpha<0.05$). RESULTS: Inter-individual differences accounted for 64% of the total variance in the non-stationary period and 30% of the total variance in the MedPF. The mean period of non-stationarity was 1268 ms, 980 ms, and 683 ms ($p<0.05$) for the 5%, 10% and 15%MVC/second force rates, respectively. The mean MedPF was 98 Hz, 86 Hz, and 125 Hz ($p<0.001$) for the 5%, 10% and 15%MVC/second force rates, respectively. CONCLUSIONS: The shortening of the non-stationary period with increasing force generation rate is consistent with greater neural input and more rapid recruitment of motor units. The shift of the MedPF to higher frequencies as force generation rate increased also suggests the additional recruitment of fast-twitch motor units. Collectively, these results indicate that non-stationarity analysis of surface EMG signals may be used to evaluate motor unit recruitment in human muscles.
References: Seven, YB, et al. (2013). Respir Physiol Neurobi: 185(2).

O.3.3 *Two Degrees of Freedom EMG-Force at the Wrist in Able-Bodied Subjects Using a Minimum Number of Electrodes: Pilot Testing of Limb-Absent Subjects*

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BACKGROUND: Traditional hand-wrist prostheses provide proportional control of only 1 degree of freedom (DoF) at a time, requiring the user to mode-switch between them. Research using large numbers of electrodes on able-bodied subjects has related the EMG of the forearm muscles to two degrees of freedom at the wrist. Initial evaluation in limb-absent subjects also shows this relationship, albeit with higher errors. However, using such large numbers of electrodes in a commercial prosthesis is not presently practical. Hence, we studied the ability to extract EMG-force information using a minimum number of electrodes. METHODS: For 10 able-bodied subjects, 16 conventional bipolar electrodes were mounted transversely about the proximal forearm. The hand was secured to a load cell which measured forces generated during wrist extension-flexion, radial-ulnar deviation and pronation-supination. A screen target produced slowly-moving (quasi-static) force targets along one of these three contraction dimensions per trial, and also produced targets with equal levels of co-contraction for pairs of dimensions (2-DoF tasks).

Effort ranged over 0-30% MVC. Linear, static, 1-DoF and 2-DoF models relating EMG amplitude to force were then trained, using regularized linear least squares. Initially, all 16 electrodes were used as inputs. Thereafter, backward stepwise selection of the training data sequentially reduced the number of electrodes. RMS error on a separate test trial was evaluated at each step. RESULTS: For 1-DoF models, stepping down to fewer than two electrodes was unacceptable; and retaining more than two electrodes provided limited benefit. This result was expected and consistent with existing prosthesis practice. With 2 electrodes, the 1-DoF average error ranged from 6.5-9.5%, depending on the DoF; pronation-supination exhibited the highest errors. For 2-DoF tasks, there was little or no change in error stepping from 16 down to 4 electrodes. Errors generally increased progressively as the number of selected electrodes decreased from 4 to 1. With 4 electrodes, the 2-DoF error averaged 6.3-8.1%, depending on the DoFs. Minimum errors occurred when combining flexion-extension with ulnar-radial deviation. This experiment was piloted with 4 unilateral limb-absent subjects. Force was measured from their sound side and mirrored contractions produced on the limb-absent side. Electrodes were mounted on the limb-absent side. For 1-DoF models using 2 electrodes, errors ranged from 12.8-18.3%, depending on the DoF. For 2-DoF models using 4 electrodes, errors ranged from 13.8-16.1%. Result trends matched those of the able-bodied subjects, but with higher errors overall. CONCLUSION: These results are encouraging that as few as 4 conventional electrodes, optimally located about the forearm, could provide 2 DoFs of simultaneous, independent and proportional control with error rates similar to the 1-DoF approach currently used for commercial prosthesis control.

O.3.4 ***A comparison of Spike Shape Measures from Surface and Indwelling Electromyography during Elbow Flexion Isometric Ramp Contractions***

Lara Green[1], Anita Christie[2], J. Greig Inglis[1], David Gabriel[1]

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BACKGROUND AND AIM: Surface EMG provides a global estimate of muscle activity, however the signal must pass from the muscle through fascia, fat, and skin, which acts as a physiological low-pass filter. Alternatively, indwelling EMG has the ability to identify individual motor units, however, only the few motor units located closest to the needle are recorded. The use of spike shape measures, rather than traditional

amplitude and frequency measures, may provide a better comparison between surface and indwelling EMG recordings. The purpose of this research was to compare five spike shape measures obtained from surface and indwelling EMG of the biceps during a slow ramp contraction to 100% maximal elbow flexion force. METHODS: Eleven participants completed ramp contractions to 100% maximal force at a rate of 10%/sec. Electromyography was recorded from the medial head of the biceps brachii. Surface EMG was recorded in a bipolar electrode configuration. Indwelling EMG was recorded using a quadrifilar needle consisting of a 25-gauge stainless steel cannula housing 4 platinum-iridium wires 50 μm in diameter. Surface and indwelling EMG data was assessed across 22 epochs, 500 ms in duration, starting from the onset of the contraction. For each 500 ms epoch traditional (root-mean-square amplitude and mean power frequency) and spike shape measures (see Figure; mean spike amplitude, duration, slope, frequency, and number of peaks) were calculated for both surface and indwelling EMG. RESULTS: All measures had a significant interaction between electrode types across epochs. However, inspection of the amplitude measures (RMS, MSA, and MSS) shows that each of the three measures, calculated from both surface and indwelling EMG, followed the same general pattern across epochs. Alternatively, the frequency measures (MPF, MSF, and MSD) had different patterns depending on the electrode type and across the three measures. The amplitude traces can be characterized as a curvilinear pattern beginning with a linear increase until approximately 75-80% maximal force was reached, followed by a slight plateau and subsequent decrease as the end of the contraction neared. CONCLUSIONS: The similarity of patterns between surface and indwelling is explicable since wave cancellation has been shown to affect the magnitude but not the shape of amplitude measures (Keenan et al., 2005). The three measures of frequency; MPF, MSF, and MSD; demonstrated a nearly identical pattern across the three measures for surface, but not indwelling, recordings. Analysis of the data suggests that the selection of the threshold for spike detection may be the primary cause of the differing patterns. It is evident that EMG measures can be affected by physiological changes (force gradation across epochs) as well as methodological differences between the types of electrodes (surface vs indwelling) and types of analysis (interference pattern vs spike shape). This work was supported by NSERC

O.3.5 *On the Usability of Rejection Capable Support Vector Machines in an Online Virtual Targeting Task*

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BACKGROUND AND AIMS: Myoelectric prosthetic control - the use of electromyographic (EMG) signals to control an artificial limb - has been under investigation for decades. A major active area of research is in pattern recognition (PR), in which EMG signals are classified based on sample contractions representing common hand and wrist motions. While PR carries tremendous promise for intuitive and realistic control of prostheses, it remains underused outside of laboratory settings due to poor robustness. The support vector machine (SVM) classifier is more accurate in offline testing than the current standard, linear discriminant analysis (LDA), and produces a more granular confidence metric, which should allow more robust rejection of misclassified contractions. Thus, the objective of this study was to determine the usability of an SVM rejection classifier as compared to LDA. METHODS: Ten subjects (six male, 26.0 ± 4.7 years) participated in two experimental sessions. In each session, they first provided sample contractions which were used to train four classifiers: LDA, LDA with rejection (LDAR), SVM, and SVM with rejection (SVMR). The subjects were then presented with a Fitts' Law-based virtual targeting task; all four classifiers were used for this task, presented in random order. In the first experimental session, the cursor moved according to a class-normalized proportional control system; in the second, a standard mean-intensity proportional control system was used. RESULTS: SVMR outperformed LDA in all six Fitts' Law measures ($p < 0.05$), SVM in three (path efficiency, overshoot, and stopping distance), and LDAR in two (path efficiency and overshoot). Proportional Control showed a significant main effect in two measures (path efficiency and stopping distance), with the standard proportional control performing better than the normalized control in both cases. The fact that proportional control had a significant effect on the measures that SVMR excelled in prompted a deeper investigation. It was found that the SVMR predominantly outperformed the LDAR at low intensity levels, leading to improved performance with smaller targets, particularly with respect to stopping. The normalized proportional control scheme, however, was found to restrict these low-intensity movements, mitigating the benefits. This appears to be due to differences in the way classifier boundaries are calculated: SVM boundaries are calculated at the margins of the data, and are thus more sensitive to thresholding effects than LDA

boundaries, which are based on the centroid and covariance matrix. CONCLUSIONS: While the SVMR generally outperformed the LDAR, the improvement was not as substantial as found in previous offline analyses. To better understand this, ongoing work is looking further into the interactions between classifier characteristics and proportional control schemes.

O.3.6 *Towards Improving the Training of Pattern Recognition Based Myoelectric Control*

Kadie Wright[1], Kevin Englehart[1], Erik Scheme[1]

[1]Institute of Biomedical Engineering

BACKGROUND AND AIM: Pattern recognition based myoelectric control has recently begun to see deployment in clinical use. One major challenge, however, is the need to conveniently and effectively train and retrain these systems. Even with prosthesis guided training, which allows the users to decouple from a training screen, the process remains cumbersome and unintuitive. The purpose of this research is to improve the training of these systems by better understanding the effects of user errors, and integrating more intelligent data processing and segmentation techniques. By looking at the effects of simulated mistakes (delayed response to prompts, or incorrect motions) that commonly occur during training, the challenges associated with different training methods can be better understood. These initial findings are being used to better understand the dynamics of training, and to develop new training algorithms. METHODS: To simulate training mistakes, 15 subjects were fitted with a flexible cuff with eight bipolar electrodes and were asked to elicit contractions corresponding to common prosthetic functions (such as wrist rotation or hand open). Offline analysis of motion classification accuracy was performed while artificially delaying the data onset, as well as swapping out specific training repetitions with incorrect motions. RESULTS: Figure 1a shows the drop in classification accuracy with increasing delay in user response to prompted motions (using a using linear discriminant analysis (LDA) classifier). Figure 1b shows the effect on classification accuracy as one training motion (wrist pronation) is replaced with that of a different motion (wrist supination) from 0 to 100 percent of that training repetition. CONCLUSIONS: These initial results indicate that the accuracy of a myoelectric classifier is greatly impacted by even minimal simulated errors during

training. Ongoing work is investigating alternative training modalities that could reduce the incidence of training errors. Additionally, we are developing a novel unsupervised segmentation algorithm that will be able to detect and compensate for the effects of these common mistakes during classifier training.

O.4. Rehabilitation Technologies II

O.4.1 *Cranial Nerve Non-Invasive Neuromodulation for Symptomatic Treatment of Mild and Moderate Traumatic Brain Injury - Effects on Muscle Coordination Patterns during Walking*

Samuel Acuña[1], Mitchell Tyler[1], Yuri Danilov[1], Darryl Thelen[1]

[1]University of Wisconsin-Madison

BACKGROUND AND AIM: The objective of this on-going study is to investigate the influence of a cranial nerve non-invasive neuromodulation (CN-NINM) on gait in individuals with chronic symptoms of chronic mild to moderate traumatic brain injury (mTBI). CN-NINM is used to enhance neuroplasticity during rehabilitation, thereby improving the brain's ability to functionally compensate for neural tissues damaged or compromised by mTBI. The aim of this study was to investigate whether CN-NINM can fundamentally alter the underlying muscular coordination patterns observed during treadmill walking. METHODS: We have developed a portable electrotactile stimulation system (PoNS) to stimulate cranial nerves V and VII via an electrode array placed on the human tongue. We are currently conducting a double-blind clinical trial to assess the efficacy of the PoNS device for enhancing neurorehabilitation of gait and balance. The study enrolls 44 subjects: 22 with an active PoNS, 22 with a sham device. All subjects perform rehabilitation exercises 3x per day with the assigned device for 2 weeks in the clinic. Clinical metrics of gait and balance are obtained prior to training and at 2, 14, and 26 weeks. We collect electromyogram (EMG) data during gait as a metric of neuromuscular coordination. Surface EMG during walking was collected on a treadmill for 60 seconds at each subject's baseline preferred speed for six muscles on each leg (Tibialis Anterior, Medial Gastrocnemius, Soleus, Vastus Lateralis, Rectus Femoris, Semitendinosus). All EMG was bandpass

filtered (1-350Hz), rectified, and then low-pass filtered at 10Hz. EMG was averaged over all gait cycles and normalized to the muscle's rms EMG activity. The protocol was repeated on 8 healthy young adults. We cross-correlated individual mTBI muscle activation patterns with the healthy controls to assess the regularity of the muscle activations both before and after 2 weeks of rehabilitation. The Dynamic Gait Index (DGI) was also performed. RESULTS: The mTBI subjects entered the study with an average DGI of 18 (±6), putting them at an increased falls risk. There was a significant (p=0.006) improvement in the DGI to 21 (±6) following 2 weeks of rehabilitation. A number of individual mTBI subjects exhibited improved phasing of plantarflexor muscle activities. Univariate correlations revealed a significant (p=0.04) improvement in the consistency of soleus activation patterns, and a tendency (p=0.095) toward improvement in the gastrocnemius. CONCLUSIONS: CN-NINM is a new integrative therapeutic intervention that used the tongue to stimulate cranial nerves for the purpose of enhancing neuroplasticity during rehabilitative exercises. With 17 subjects enrolled, we are already seeing a significant improvement in clinical gait metrics. While we remain blind to which subjects are receiving active PoNS devices, there is an inconsistent effect across subjects with 4 individuals exhibiting remarkable (>4) improvements in the DGI.

O.4.2 *What does the CNS see during electrically stimulated muscle contractions?*

Patrick Crago[1]

[1]Case Western Reserve University

BACKGROUND AND AIM: Muscle stimulation is applied for therapeutic or neuroprosthetic benefit, including pain or spasticity reduction, and rehabilitation or augmentation of impaired motor control. Stimulation generates centrally conducted action potentials in both motor efferents and muscle receptor afferents, and the stimulated action potentials are mixed with ongoing neural activity supporting muscle control. To what extent are the resulting action potential patterns analogous to those evoked by normal muscle activity? Action potential patterns that result from muscle stimulation have not been well characterized. During stimulation via intramuscular, muscle nerve, or skin surface electrodes, action potentials propagating to the CNS are elicited in large diameter (low threshold) axons including motor efferents and proprioceptive afferents from muscle spindles (Ia) and tendon organs

(Ib), whose axons are co-located and have similar stimulation thresholds. A stimulus generates a pair of action potentials travelling distally and proximally. Thus, each stimulated axon combines antidromic and orthodromic action potentials generated by the stimulus mixed with action potentials generated by physiological processes. METHODS: This report focuses on the responses of tendon organs to both voluntary and stimulated contractions, including the effects of simultaneous Ib afferent stimulation. Action potential patterns are characterized by numerical simulation of human first dorsal interosseus contractions. The muscle model includes individual motor units and a population of tendon organs. Action potential antidromic-orthodromic interaction models include collision, refractory periods, and resetting of tendon organs by stimulus generated action potentials. RESULTS: Ib firing rates increase with increasing force level, achieved by increasing physiological excitation level, stimulus rate, or stimulus recruitment. Simultaneous Ib stimulation increases the action potential rate in a nonlinear manner. The average rate (calculated as the number of action potentials in a time window) is the lowest integer multiple of the stimulus rate that exceeds the receptor firing rate. Thus, for a fixed stimulus rate, increasing the receptor firing rate increases the Ib rate in a nearly staircase fashion. Low stimulus rates show a greater number of stair steps (i.e., better resolution) than higher rates. The net rate increment of a uniformly distributed population of tendon organs is approximately one half the stimulus rate. Therefore high rates offer the greatest increase in net firing rate. CONCLUSIONS: Stimulation of tendon organ afferents significantly disrupts their force coding accuracy. Increasing the stimulus rate increases the average firing rate but lowers resolution. Similar effects on sensory coding would be expected from stimulation of any afferent axon.

O.4.3 *Does the distance between electrodes markedly affect the knee extension torque elicited in tetanic, stimulated contractions?*

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BACKGROUND AND AIM: The parameters considered in functional electrical stimulation protocols are well described in literature. However, regarding the quadriceps muscle, indications on the positioning of stimulation electrode are missing [1,2]. In this study we specifically ask: does electrically elicited knee extension torque increase with the proximo-distal distance between cathode and anode electrodes positioned on rectus femoris (RF), vastus medialis (VM) and lateralis (VL) muscles? Considering the extensive, proximo-distal distribution of motor points within these muscles [3], we expect greater inter-electrode distances to elicit greater knee torque. METHODS: We measured the knee extension torque elicited by stimulating the femoral quadriceps of ten subjects (500 μs rectangular pulses; 20 pps). Adhesive stimulation electrodes were positioned to obtain current lines directed longitudinally to the each muscle. By taking as reference the femoral length (FL), defined as the distance between the patella apex and the anterior superior iliac spine, we tested four inter-electrode distances: 12.5%FL (L1), 25.0%FL (L2), 37.5%FL (L3) and 50.0%FL (L4). The position of the cathode electrode was fixed at 20%FL. For each configuration tested, we progressively increased current intensity at 10 mA steps, from 0 mA to the maximally tolerated intensity. Non-parametric Friedman ANOVA was used for the multiple comparisons and Wilcoxon test for the paired comparison, with Bonferroni correction. RESULTS: As expected, electrode positioning affected markedly the maximally elicited, knee extension torque. For the L1 and L2 configurations, knee extension torque did not increase after the stimulation intensity reached a certain value. In contrast, for L3 and L4, knee torque increased proportionally with the stimulation intensity. The maximal torque values elicited for L3 (interquartile interval: 70-125 Nm; N=10 subjects) and L4 (90-140 Nm) were on average 2-3 times greater ($p<0.05$) than those obtained for L1 (25-40 Nm) and L2 (55-70 Nm). The maximal current tolerated by each participant ranged from 60 mA to 100 mA and did not depend on the inter-electrode distance. CONCLUSIONS Key results revealed that: i) for small inter-electrode distances, increases in knee torque ceased after the current intensity reached a certain value; ii) the maximal extension torque increased dramatically with inter-electrode distance. Collectively, these results indicate the position of stimulation electrodes critically affects the elicited torque, with potential, significant implications for the optimisation of protocols based on functional electrical stimulation. [1] Davoodi R. et al. IEEE Trans Neural Syst Rehabil Eng. (2002); 10: 197-203. [2] Benton L.A. et al. FES - A practical clinical guide, Rehab Eng, Downey, 1980 [3] Botter A. et al. Eur J Appl Physiol (2011); 111: 2461-2471.

O.4.4 *Sensory and Motor Thresholds for Surface Electrical Stimulation of Median and Ulnar Nerves at Elbow for Sensory Feedback*

ISEK ORAL ABSTRACT BOOKLET
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BACKGROUND AND AIM: Loss of the sensory input for trans-radial amputees may lead to maladaptation in the sensory cortex, causing phantom limb pain (PLP). Restoring part of the lost sensory input through sensory feedback evoked by electrical stimulation may induce plastic cortical changes and alleviate PLP to some degree. Sensory and motor thresholds for surface electrical stimulation of ulnar and median nerves at elbow evoking hand sensations in healthy subjects have been investigated. The study aimed to optimize parameters of the electrical stimuli evoking hand sensations without eliciting motor responses in 10 healthy subjects. METHODS: For each nerve, one pair of round PALS electrodes with diameter of 32 mm was placed at elbow. To stimulate the ulnar nerve, one electrode was placed just above the cubital tunnel, with reference to the medial epicondyle of the humerus and the olecranon of the ulna, and the other was placed proximal towards the median side of the humerus. One electrode was placed lateral to the biceps tendon and the other was placed distal along the ulna when stimulating the median nerve. Current controlled biphasic stimuli of increasing amplitude of 0.5 mA, frequency of 10 and 50 Hz, and pulse duration of 100, 200, and 300 msec were delivered by the Inomed neurostimulator to both nerves during one session of approximately 3 hours. The subjects reported location of evoked sensations in areas of the palmar side of the hand corresponding to innervation by median and ulnar nerves. RESULTS: Sensation thresholds of 5.88 %2B/- 1.04 mA and 8.16 %2B/- 1.75 mA and motor thresholds of 8.01 %2B/- 1.76 mA and 11.65 %2B/- 1.74 mA were obtained for the median and ulnar nerve, respectively. Stimuli with frequency of 50 and 10 Hz and pulse duration of 200 and 300 msec evoked sensations without motor response in 27.9 and 32.3 % of the area of palmar side of the hand for ulnar and median nerve, respectively. The pulse duration and frequency showed a modulating effect on the sensory and motor thresholds for both nerves ($p < 0.05$, 3-way ANOVA). CONCLUSIONS: Hand sensations were consistently evoked by surface electrical stimulation of the median and ulnar nerves at elbow for sensory feedback.

O.4.5 ***The effect of rehabilitation with the neuromuscular electrical stimulation after femoral neck fracture surgery -Short term intervention reports-***

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Electrophysiology and Kinesiology

ISEK ORAL ABSTRACT BOOKLET
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Background and Aim: Following femoral neck fracture treatment, lower leg muscle atrophy and weakness were caused by immobilization and inflammation. It is important that patients start to rehabilitation during early post-operative period in order to prevent muscle atrophy and maintain muscle strength, which is often used the neuromuscular electrical stimulation (NMES). Past researchers studied the effectiveness after total knee arthroplasty or femoral fracture treatment. However, there were few studies about the comparison of the effect by using the NMES after the Bipolar hip arthroplasty surgery. Our purpose of this study was to compare the differences of the clinical results between the Bipolar hip arthroplasty (BHA) with the NMES and control group. Methods: Eighteen patients were randomly divided in 2 groups: BHA with NMES (9 patients) and no NMES group (control, 9 patients). There were no differences about the age, height and weight between BHA with NMES and control group. These patients received both standard rehabilitation and, in the NMES groups, two pairs of adhesive electrodes were displayed the femoral nerve and the quadriceps muscle to mitigate strength loss. The NMES unit we used (ESPURGE, Ito Co., JPN) provides an asymmetric biphasic pulse waveform, pulse duration of 300 µs. The frequency was 80 Hz. NMES was applied 20 minutes per day at the maximal tolerable intensity for 4 weeks after surgery. We analyzed the knee extensor muscle strength by using the hand held dynamometer and Japanese Orthopedic Association Scoring (JOA) at 1 week, 2 weeks, 3 weeks and 4 weeks after surgery. JOA score were consisted of pain, Range of Motion (ROM), gait ability, and Activity of daily life (ADL). Student t test assessed the differences in the muscle strength and JOA among three groups. Results: As for the comparison of muscle strength, the results of BHA with NMES were significantly better than these of control at 1 week ($p<0.01$), 2 weeks ($p<0.01$), 3 weeks ($p<0.01$) and 4 weeks ($p=0.025$). And the JOA score were significantly better in the BHA with NMES compared with the control at 1 week ($p<0.01$), 2 weeks ($p<0.01$), 3 weeks ($p<0.01$) and 4 weeks ($p<0.01$). Conclusions: The inclusion of the neuromuscular electrical stimulation (NMES) program after BHA surgery was more effective at providing rapid improvements in muscle strength than control. And the JOA score of BHA with NMES were significantly higher than that of

control. We suggest that the difference in muscle strength between BHA with NMES and control after surgery was brought about by the prevention muscle atrophy by NMES using for 4 weeks. Furthermore, our data also supported the increased muscle strength were influenced on JOA score. In the future, it should be further followed up the patients to investigate the long-term outcomes.

O.4.6 *The cortical adaptation monitoring system for leg press machine with FES induced biofeedback*

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BACKGROUND AND AIM: For the purpose of effective training of paralysis, Functional Electrical Stimulation(FES) provides both muscular training and sensory stimulation for the brain. Combination of muscular synergy effect and the brain plasticity is new key issue of robotic rehabilitation. The conventional FES system is applied mainly for the tentative training, however it has been disturbed for long term recovery of motor function, since the difficulties of keeping motivation. FES system required long time trial and error training without any feedback. This boring process is one big reason for losing motivation. Therefore, evaluations of training effect are desired to provide feedback to the trainees to keep motivation. FES has shown its effectiveness in the recovery of motor function. It can promote recovery of muscular force and induce brain plasticity by somatosensory feedback. This study investigated the generality of brain responses during voluntary exercise associated with FES which has the effect of training (motor learning). METHODS: The subjects were separated into two groups. One group performed leg press training while undergoing FES. We stimulated subject's left quadriceps muscle with the FES device for one second. The subjects controlled the timing of FES to provide FES induced biofeedback. We thought that FES is assist for leg press training. The other group only performed voluntary leg press training. The subjects were seated in the chair of the leg press device(Fig.1). The subjects were required to control the position quickly and accurately during high-intensity exercise. The NIRS measurement covered the primary motor cortex and the somatosensory cortex with transmitters and receivers. Receiver No.5 was positioned on the Cz of the international 10-20 system. The

subjects performed leg press training twenty times per experiment. RESULTS: We constructed a measurement system for leg press training with FES induced biofeedback. Both knee joint angle and brain activity during training are measured and synchronized by an external signal. We monitored the brain activity of healthy subjects with NIRS over a three-month period (once per day) during which the knee joint movement was induced by FES. The motion performance results showed that the dispersal of position error was smaller with FES(Fig.1 left and right). CONCLUSIONS: The experiment results suggested that FES has efficacy as power assist in motor training. This monitoring system might well be able to evaluate training effects during FES induced biofeedback. Further research will examine patients suffering from paralysis to determine the optimum stimulation parameters for brain activation to involve brain plasticity.

O.5. Neuromechanics II

O.5.1 *Effect of Lower Extremity Efforts on Involuntary Upper Extremity Activity in Chronic Hemiparetic Stroke: Preliminary Findings*

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INTRODUCTION: Following hemiparetic stroke, individuals often manifest altered interlimb coupling patterns. High efforts in the lower extremities can cause involuntary upper extremity movements, which interfere with gait, balance reactions, activities of daily living, and have negative cosmetic effects. Abnormal interlimb coupling is hypothesized to be due to an upregulation of brainstem motor pathways (reticulospinal and vestibulospinal tracts), which branch extensively in the spinal cord. While abnormal coupling patterns within both the upper and lower extremity have been previously quantified, coupling patterns between limbs are poorly understood. The aim of this project was to quantify the effect of lower extremity tasks on involuntary activation of the upper extremity in individuals with chronic stroke. METHODS: 12 individuals with chronic stroke and 7 age-matched controls were recruited for this study. A novel robotic application was used to support the upper

extremity with haptic springs. This approach allowed for the quantification of upper extremity kinematics and kinetics, while negating the weight of the upper extremity and preventing participants from using their upper extremity as a rigid ground to gain biomechanical advantage. Participants performed maximal and submaximal (25, 50, and 75%) voluntary isometric knee flexion and extension contractions while instructed to relax their upper extremity. In a separate condition, participants were asked to suppress their upper extremity activity. Both paretic and non-paretic upper extremities were tested with each leg. In control participants, the non-dominant arm was tested with both legs. RESULTS: Control participants were able to isolate the lower extremity efforts, with no significant upper extremity activity. In individuals with chronic stroke, lower extremity efforts resulted in involuntary upper extremity activity that was dependent on the level of effort in the lower extremity. Both paretic and non-paretic knee flexion and extension elicited involuntary upper extremity movement. While the involuntary movement was greater in the paretic arm, the non-paretic arm also had activity that was greater than in control participants. Shoulder adduction was elicited in the majority of stroke participants regardless of the lower extremity task, while there was a trend for knee extension resulting in elbow extension and knee flexion causing elbow flexion. When asked to suppress the upper extremity motion, stroke participants were unable to significantly reduce their arm motion or produce the same level of lower extremity torque.
DISCUSION/CONCLUSIONS: The results of this study show that individuals with chronic stroke have altered interlimb coupling patterns that are dependent on the level of descending motor drive. The findings suggest that the underlying mechanism for altered interlimb coupling is an increased use brainstem pathways with increased task demands.

O.5.2 *Variability in neuromotor control of the musculoskeletal system dynamics: a stochastic modelling approach.*

Bart van Veen[1], Saulo Martelli[2], Claudia Mazzà[1], Erkki Somersalo[3], Daniela Calvetti[3], Marco Viceconti[1]

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Introduction The number of muscles in the human motor system exceeding the number of kinematic degrees of freedom (DOF) [1] allows the motor control system to select one neuromotor control strategy from many options. Even when pursuing the same strategy, however, structured variability exists in the muscle activations and end-effector forces recorded [2]. A stochastic method (Metabolica) has been used to sample the space of possible muscle force patterns that balance the net joint moments throughout a movement [3]. Static optimization techniques have been used to separately determine the boundaries of the corresponding space of muscle activation patterns [4]. The aim of this study is to compare the boundaries of the spectrum sampled using Metabolica for an increasing sample size with corresponding boundaries calculated using static optimization. This information is necessary towards the design of a probabilistic framework for studying subject-specific control strategies. Methods Gait analysis data were collected for one gait cycle of one healthy subject (male, age: 28 yr., height: 1.90 m) and net joint moments and muscle lever arms were estimated using the Opensim Gait2392 model with 13 DOF and 92 muscles [5]. The force each muscle could produce was constrained by its tetanic isometric force at optimal fibre length. The solution space of the constrained equilibrium equation at the joints was sampled using Metabolica with the following sample sizes: 1e5, 2e5, 3e5 and 1e6. The reference boundaries of the solution space were calculated through static optimizations that separately minimized and maximized the force of each muscle. The ranges of muscle force identified by the two methods were compared. Results and discussion For a sample size of 1e5, the sampled muscle force ranges grossly underestimated the optimized force ranges. For 2e5 samples, the samples covered the whole range for most muscles, while for some muscles (including gluteus maximus, vasti and soleus) the range sampled with Metabolica was smaller than the optimized range, as shown by non-red areas in Figure 1, indicating extreme forces to be highly improbable. Following increases in sample size did not generate evident changes in the results. This is likely to be attributed to the fact that a change in the force of certain muscles constrains the possible force contribution of other muscles. Future studies will focus on using EMG and kinematic data from repeated movements in order to define a layer of probability associated with the sampled force patterns to represent individual variability. Acknowledgement This project was funded by the EPSRC Frontier Engineering Awards, Grant Reference No. EP/K03877X/1. References [1] Bernstein NA. Oxford: Pergamon Press 1967 [2] Valero-Cuevas FJ, et al. J Neurophysiol 2009;102:59-68 [3] Martelli S, et al. J Biomech 2013;46:2097-2100 [4] Simpson CS, et al. J Biomech 2015;48:2990-2997 [5] Delp SL, et al. IEEE Trans. Biomed. Eng. 2007;54:1940-1950

O.5.3 ***From muscle-tendon to whole-body dynamics: towards a multi-scale empirical understanding of human movement biomechanics***

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BACKGROUND AND AIM: A grand challenge in the field of biomechanics is to develop a cohesive, multi-scale understanding of human movement that links muscle-tendon, joint and whole-body dynamics. Musculoskeletal simulations have been developed to help bridge these gaps; however, these computational models are difficult to validate due to parameterization complexity and anatomical/physiological uncertainties. Empirical methods could potentially overcome these limitations by more directly measuring human biomechanics, but the challenge remains to improve quantitative agreement between our various experimental estimates. Using traditional 3D analysis, biomechanical estimates at one scale often do not agree with estimates at another. For instance, net mechanical work computed about the joints when a person climbs a set of stairs overestimates the work performed to raise the center-of-mass against gravity (Duncan et al. 1997). Even for level ground walking, work discrepancies of 25-35% have been observed (Zelik et al. 2015). Likewise, muscle-tendon work estimates derived from ultrasound and force transducers may not be fully consistent with joint work estimates from inverse dynamics. It is critical to resolve these discrepancies in order to develop a comprehensive, multi-scale understanding of movement. This abstract summarizes our recent efforts to coalesce multi-scale estimates. METHODS: In one study we integrated various empirical estimates of work and energy in order to synthesize whole-body dynamics (from Fenn 1930, and Cavagna et al. 1963 traditions) with joint- and segment-level kinetics (from Braune and Fischer 1895, and Elftman 1939 traditions). In a second study we focused on developing and validating an EMG-driven musculoskeletal analysis to partition joint kinetics into contributions from individual muscle-tendon units. We are now working to parse muscle fiber vs. tendon work by incorporating ultrasound. RESULTS AND CONCLUSIONS: We demonstrated, for the first time, that joint-segment estimates could fully capture whole-body gait

dynamics (work done on/about the center-of-mass, Zelik et al. 2015). We found that the key to resolving work discrepancies was using 6 degree-of-freedom (rotational and translational) analysis of the hip, knee, ankle and foot. Next, we demonstrated that a new EMG-driven analysis could reproduce inverse dynamics sagittal ankle power with high fidelity during walking (R^2=0.98, Honert and Zelik 2016, in review), while providing estimates of individual muscle-tendon contributions. Future work remains to validate this approach for different joints, activities, and planes (non-sagittal). The next challenge is to parse muscle fiber vs. tendon work. Although historically difficult, advances in medical imaging (e.g., ultrasound) offer promise. We will discuss ongoing efforts to reliably quantify muscle-tendon length changes and forces during movement, and to synthesize these with our multi-scale biomechanical understanding.

O.5.4 *The same library of muscle synergies are shared across diverse locomotor tasks*

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BACKGROUND AND AIMS: Previous research has suggested that human movement is controlled by a "mixed" modular strategy that includes both shared (task-independent) and specific (task-dependent) muscle synergies (i.e. consistent time-synchronous multi-muscle coordination patterns). However, prior studies have been insufficient to fully characterize how muscle synergies are recruited across a range of locomotor tasks because of the limited number and diversity of the tasks they examined. It is possible that the muscle synergies considered task-specific are recruited during other non-measured behaviors. The aim of this study was to investigate muscle synergies across a large number of diverse locomotor tasks. We hypothesize that locomotor tasks are controlled by a library of task-independent muscle synergies. METHODS: One healthy, young adult (M, 25 years old) performed 18 diverse locomotor tasks that included walking at a range of speeds/directions, with different stepping patterns, turning with different radii, and maneuvering around obstacles and across uneven terrain. EMG was collected from 16 leg and trunk muscles on the right side. We identified the set of unique muscle synergies recruited across all tasks using a two-step process. In step one, muscle synergies

were extracted separately from each task using non-negative matrix factorization (NMF). The number of muscle synergies for each task was chosen such that the overall variability accounted for (VAF) of the reconstructed EMG was ≥ 90%. Then in step two, the muscle synergies extracted from each task in step one were pooled together and grouped using a hierarchical cluster analysis (CA). The number of unique muscle synergies was determined by identifying the minimum number of clusters such that each cluster did not contain multiple muscle synergies from the same task. As a secondary validation, we also extracted a set of unique muscle synergies from a data matrix containing all data from all tasks (joint extraction, JE), where the number of unique muscle synergies was chosen such that overall VAF for each task was ≥ 90%. RESULTS: We found a total of 13 unique muscle synergies using the CA method that could describe the muscle activity from all 16 muscles during all 18 locomotor tasks. 6.8±1.0 (mean±SD) of these muscle synergies were recruited per task and each muscle synergy was recruited in more than one task (mean number of tasks per muscle synergy: CA=9.4±4.8, range 5-17). The JE method identified an equivalent number of muscle synergies, 12, which were found to be similar in structure to those identified using the CA method (Pearson's R=0.83±0.12), and were also recruited across multiple tasks (12.6±2.7). CONCLUSIONS: By examining a large number of locomotor tasks encompassing diverse functional demands we found that all muscle synergies were recruited across multiple tasks, supporting our hypothesis that locomotion is controlled by a library of task-independent muscle synergies.

O.5.5 ***Decreasing the lumbar flexion moment induces earlier onset of flexion relaxation***

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BACKGROUND AND AIM: Flexion relaxation (FR) is characterized by a reduction in lumbar erector spinae (LES) muscle activation near end range of trunk flexion. FR is believed to occur as passive spine structures (ligaments, discs, and passive muscles), which are slack in a neutral spine position, become engaged and support the lumbar moment. The engagement of passive structures allows lumbar muscles to cease active force production. Consistent with this theory, increasing the lumbar moment

by adding mass to the torso has been shown to delay the onset of FR [1]. The purpose of this study was to determine if experimentally decreasing the lumbar moment produced the opposite effect, inducing FR to occur earlier. A secondary purpose was to characterize how the lumbar moment affected thoracic and abdominal muscle activity during trunk flexion. METHODS: Ten healthy males (25 ± 2.5 years, 181 ± 5.8 cm, and 82 ± 11.2 kg) performed four trunk flexion conditions; lumbar moment was reduced by attaching 0, 5, 10, or 15 lb counterweights to the torso with a pulley. Muscle activity was recorded using fine wire electromyography (EMG) from lumbar multifidus and surface EMG from LES, thoracic erector spinae (TES), latissimus dorsi (LD), rectus abdominus (RA), and external (EO) and internal oblique (IO). Kinetic and kinematic data were input into a custom two dimensional, dynamic rigid linked segment model to determine the lumbar moment. Lumbar moment, lumbar flexion angle (between T12 and S1 spinous processes) and trunk inclination angle (between T12 and horizontal) at the critical point when LES became inactive (CPLES) were compared between conditions. RESULTS: Counterweights decreased the lumbar moment and lumbar flexion angle at CPLES ($p < 0.0001$ and $p = 0.0029$, respectively); however, there was no effect on trunk inclination at CPLES. Multifidus demonstrated FR similar to LES, while TES and LD remained active throughout trunk flexion. RA, EO, and IO activated at the same instant that LES inactivated, except in the 15 lb condition where abdominal muscles became active approximately 1 s before CPLES. CONCLUSIONS: The hypothesis that FR would occur earlier when the lumbar moment was reduced was accepted. This provides further evidence that FR occurs when the lumbar moment is equilibrated by passive structures. Thoracic and abdominal muscles actively produced force at end range of trunk flexion. As both thoracic and abdominal muscles affect the lumbar spine moment, changes in mechanics or activation of these muscles may affect presentation of FR. REFERENCES: [1] Howarth SJ, Mastragostino P (2013). J Biomech Eng.135(10); p1-6.

O.5.6 *Estimation of Ankle Impedance During Walking on a Slippery Surface*

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BACKGROUND AND AIM: Walking safely on a slippery surface is a difficult task and failure to do so can result in falls and injuries. This challenge is increased for lower-limb amputees, as their ability to change gait patterns is constrained by the dynamics of the prosthetic leg, which typically do not adapt to changing surfaces. We previously demonstrated that able-bodied subjects reduce slip potential in part by reducing ankle muscle activity, which has been linked to a reduction in joint impedance. This finding could be used to program the impedance of robotic prostheses, which are becoming more prevalent. However, we do not yet know how the observed reduction in muscle activity influences the net impedance of the ankle. The objective of this work was to quantify ankle impedance for able-bodied subjects walking on a non-slippery and slippery walkway. Based on previous work, we hypothesized there would be a reduction in the stiffness component of ankle impedance on the slippery walkway. METHODS: Three able-bodied subjects completed a protocol in which they walked across a non-slippery walkway (coefficient of friction (COF) > 0.4) and a slippery walkway (COF $= 0.17 \pm 0.01$). Embedded halfway down the walkway was the Perturberator Robot, a device that can be used to estimate ankle impedance during the stance phase of gait. When subjects stepped onto the robot, it randomly delivered a 2-degree ramp-and-hold perturbation. Perturbations occurred randomly in either the plantarflexion or dorsiflexion direction at 150, 300, or 450 ms after heel contact. Perturbations occurred in 67% of the trials. System identification techniques were used to estimate ankle impedance, modeled as a second-order system with stiffness, damping, and inertia. Electromyograms (EMGs) were recorded from select ankle muscles, including medial gastrocnemius (MG) and tibialis anterior (TA). EMG was quantified using root-mean-square over the same range of data used for impedance estimation. RESULTS: Even though there was a reduction in EMG on the slippery walkway, there was no concurrent reduction in joint stiffness. MG EMG was significantly reduced ($p=0.004$) by 18% and TA EMG was significantly reduced ($p=0.027$) by 13% on the slippery walkway. There was, however, no difference in stiffness between the walkways ($p=0.406$). CONCLUSIONS: These results suggest that the muscles recorded in this study, which are easily accessible using surface EMG, cannot be used as a proxy for joint stiffness. This is in direct contrast to what has been shown for isometric contractions, implying that joint impedance is modulated differently during static tasks compared to time-varying dynamic tasks. Other parts of the joint, such as the tendon, might be setting the stiffness level under these conditions. Follow-up studies should be conducted to determine the parts of the joint that contribute to impedance modulation during locomotion.

O.6. Motor Units I

O.6.1 *Motor units in the human medial gastrocnemius muscle are not spatially localized or functionally grouped*

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BACKGROUND AND AIM: There is evidence from surface electromyography (EMG) studies of regional medial gastrocnemius (MG) muscle activation in humans, which may allow for more controlled and efficient torque generation. In line with these findings, MG motor units (MUs) are thought to occupy small muscle territories (2.5-4 cm), with low-threshold units preferentially located distally. However, the presence of regional activation in the MG muscle has been questioned. In the present study we used indwelling wire and needle EMG recordings to estimate the size and location of MG MU territories and determine whether they were grouped based on recruitment threshold or joint action. METHODS: Subjects (n = 8) performed ramped and sustained isometric contractions (ankle plantar flexion and knee flexion; range: ~1-40% maximal voluntary contraction) and we measured MU territory size with spike-triggered averages from fine-wire electrodes inserted along the length (seven electrodes) or across the width (five electrodes) of the MG muscle. RESULTS: Of 69 MUs identified along the length of the muscle, 32 spanned at least half the muscle length (≥ 6.9 cm), 11 of which spanned all recording sites (13.6-17.9 cm). Distal fibres had smaller pennation angles ($P < 0.05$), which were accompanied by larger territories in MUs with fibres located distally ($P < 0.05$). There was no distal-to-proximal pattern of muscle activation in ramp contraction ($P = 0.93$). Of 36 MUs identified across the width of the muscle, 24 spanned at least half the muscle width

(≥ 4.0 cm), 13 of which spanned all recording sites (8.0-10.8 cm). MUs were not localized (length or width) based on recruitment threshold or contraction type, nor was there a relationship between MU territory size and recruitment threshold (Spearman's rho = -0.20 and 0.13, P > 0.18). CONCLUSIONS: MUs in the human MG have larger territories than previously reported and are not localized based on recruitment threshold or joint action. In line with these observations and similar to what has been reported in the cat, we found that many MUs in the human MG muscle have territories that extend over a large portion of the muscle, with no evidence that these MUs are grouped by recruitment threshold or joint action. Together, these results lead us to propose that the human MG muscle is uniformly activated by the CNS and, more cautiously, that previous reports of regional muscle activation may reflect methodological limitations and between- and within-subject variability. Finally, these results indicated that the CNS does not have the means to selectively activate regions of the MG muscle based on task requirements.

O.6.2 ***Motor Unit Action Potential Clustering***

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Motor Unit Action Potential Clustering Michael J. Asmussen, Vinzenz von Tscharner, Benno M. Nigg Background & Aims: This study aimed to understand motor unit action potential synchronization and clustering using a modelled electromyography (EMG) signal. The power spectrum of an electromyography (EMG) signal can be sensitive to changes in the shape of motor unit action potentials (MUAPs) and MUAP firing patterns. For instance, the EMG signal from a fatiguing muscle is often associated with a shift of the mean power frequency to lower values. Dynamic tasks, such as squatting, result in similar mean power frequency shifts. The mechanism underlying this shift, however, has yet to be determined. Previous literature suggests that this low frequency shift could be attributed to the phenomenon of motor unit action potentials arriving together in a very short time window (i.e., clusters). The purpose of this study was to determine, using a modelled EMG signal, whether clustered motor unit action potentials can create differences in the corresponding power spectrum characteristics. Methods: The EMG signal was modelled by convolving a single MUAP with a randomly distributed impulse train (EMG-rand). A second EMG signal was modelled with the same MUAP and a "clustered" train of impulses that occurred in windows varying in duration from 1 to 80 ms (EMG-clust). To form the final modelled EMG signal, the EMG-clust was added to the EMG-rand with varying ratios ranging from 1:1 to 1:10. Results: The results from this study revealed that adding clustered MUAP (8 to 40 ms) to an EMG-rand signal caused a substantial low frequency shift (i.e., ~30 Hz) in the mean power frequency with the largest shift occurring with a cluster window of 16 ms. Further, the magnitude of the greatest mean frequency shift in the power spectrum was larger when the ratio of EMG-clust to EMG-rand was higher (i.e., 100% clustering: 26 Hz; 50% = 17 Hz; 33% = 13, ratio 25% = 7 Hz; 10% = 3 Hz). Conclusions: The changes in mean frequency of the modelled EMG signal in this study were similar to the frequency shifts seen experimentally during dynamic tasks. Therefore, the model created in this study potentially explains the mechanism of the mean frequency changes in the power spectrum observed in dynamics tasks such as running. While the applied model is a simplification of a typical measured surface EMG, it seems to be able to describe the phenomenon of power spectra changes in dynamic tasks.

O.6.3 *EMG envelope and tension oscillations during steady fine motor control*

Claudio Orizio[1], Francesco Negro[2], Marta Cogliati[1], Anna Castronovo[2], Dario Farina[2]

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Introduction At the beginning of motor unit (MU) recruitment, the inter-spike interval shows relatively large variability. This phenomenon can be related to large force fluctuations (Tracy et al., JAP, 2005). Studies dealing with the relation between the steadiness in muscle mechanical output and the fluctuations in the drive from the spinal motoneurons usually do not focus on the first transient phase. For this reason, there are relatively few data investigating the force transients and motor unit activity in the time interval time interval needed to reach the force target. This study aims at sheding light on this aspect of motor control, using experimental recordings of torque, bipolar EMG (SD-EMG), reflecting the overall stream of MU commands, and high density surface EMG (HD-EMG), from which a direct information on MU activity can be obtained by decomposition (Negro et al., 2016). Methods Two experiments

were performed. In the first, bipolar EMG signals (SD-EMG) were recorded from 20 subjects. In the second, HD-EMG using arrays of 64 surface electrodes were recorded in 5 subjects. In both experiments, the tension (T) was recorded during a 20-s abduction of the First Dorsal Interosseous (FDI) muscle, with target force set to 2.5% of the maximal voluntary contraction (MVC). SD-EMG study. The fluctuation of the EMG envelope (eEMGf) and of the T (Tf) were obtained by bandpass filtering the two signals (0,5-5 Hz). Average rectified values (ARV) of eEMGf and Tf was calculated second by second. HD-EMG study. Individual MU spike trains were identified through decomposition and analyzed according to Negro et al. (2009). Results SDEMG study. Through exertion, the eEMGf and Tf ARV decreased up tp 40%±5.35 and 15%±1.84yy from their initial value, respectively. The difference was statistically different. The steady state in the Tf and eEMGf ARV reduction was reached always within 4 s. HDEMG study. During the transiet to target force, the interspike interval variability for individual MUs was greater than in the steady part of the contraction (its coefficient of variation changed from about 1.2 to 0.3 from the first seconds to the steady state) . Moreover, a continuous recruitment and de-recruitment of MUs was observed. Conclusion The results from HDEMG study support the hypothesis that the initial phase of tension variability may be related to a large variability in MU firing and recruitment (this is mirrored in high eEMGf and Tf ARV values in the first 4-5 s of exertion). After this interval the motor control system provides a more stable flow of motor commands and the tension oscillations are reduced. These events can influence the mechanical output more than the eEMGf variability because of the different summation properties of MU twitches and MUAPs.

O.6.4 ***Using the Size Principle to Model Peripheral Muscle Fatigue***

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BACKGROUND AND AIM: Peripheral muscle fatigue is the decrease in the force output of motor units, and the whole muscle, for a given excitation. Fatigue models in the literature range from regression equations to complex representations of motor neuron pools and metabolic dynamics (see Dideriksen et al, 2010). An accurate, but easy to implement, fatigue model would have many applications in ergonomics, exercise, and rehabilitation. This paper describes the development and

validation of such a model, which uses size-principle based simulations to predict motor unit (MU) firing rates, MU and whole muscle force production, and their subsequent fatigue time-histories. METHODS: We used the model of Fuglevand, Winter & Patla (1993) to determine instantaneous firing rates and forces for 120 MUs, as excitation was increased from 0 to 100% MVC. We then assumed that each MU's instantaneous fatigue rate (FR) was proportional to its current force, such that higher threshold (and stronger) MUs had higher maximum FRs, and individual MUs approached their own maximum FR as they approached their maximum force. During sustained isometric contractions, each active MU was ascribed a reduction in its maximum force, over each 0.10 s epoch, according to its current exerted force and corresponding FR. In the subsequent epoch, the model determined the necessary excitation to meet the target force given the resulting force loss for each MU recruited at that excitation. Endurance time was then determined as the time, since the outset of the contraction, at which simulated muscle force could no longer match or exceed the target force, despite maximal excitation of the MU pool. Simulated endurance times were compiled for a wide range of target forces (20 to 80%, in 5% increments) and compared to those estimated from non-linear regression of measured endurance times from numerous experimental studies on human subjects. RESULTS: Overall, the model predicted endurance times remarkably well over a wide range of target forces. Across all 13 target conditions, the RMS difference between simulated and experimentally observed endurance times was 6.5%. For example, for a 20% MVC target, the model predicted an endurance time of 486 s, whereas that estimated from empirical data was 513 s (-5.3% difference). Likewise, for a 60% MVC target, the model predicted an endurance time of 79 s whereas the estimate from empirical data was 72 s (9.7% difference). CONCLUSIONS: This modelling approach shows great promise for tracking peripheral muscle fatigue during sustained, isometric efforts. The model has the added benefit of providing powerful insights into the fatigue time-histories of individual MUs during a range of constant effort demands. Further adaptations will also allow for the model to track individual motor unit and whole muscle recovery, so that any type of effort pattern can be evaluated.

O.6.5 ***Features for tracking spatial intra-cortical, electrophysiological changes in a rat model of ischemic stroke***

Rasmus Nielsen[1], Winnie Jensen[1]

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[1]Sensory-Motor Interaction

BACKGROUND AND AIM: Ischemic stroke occurs as a cascade of events from energy depletion to cell death and involve a series of pathophysiological events that evolve over time and space. To increase the complexity several of the pathological processes are ?janus-faced? in nature with both beneficial and detrimental effects. Today MRI is used as the primary tool in the acute phase in the clinic to assess anatomical and hemodynamic changes but at a relatively low temporal and spatial resolution. Preclinical animal studies have focused on histological infarct volume and sensorimotor function tests to evaluate the effects of stroke. Microwire electrode-arrays inserted in the cortex enable direct analysis of electrophysiological properties of neural networks at high spatial and temporal resolution, however the analytic focus is often on single-channel responses. The objective of the present study was therefore to establish features to quantify the spatial progression of ischemic stroke over time in an animal model of ischemic stroke. METHODS: Eight male Sprague-Dawley rats were instrumented with a 28-channel Intracortical (IC) electrode-array and a cuff electrode around the sciatic nerve. Photothrombosis intervention was performed within the hind limb area of the left sensorimotor cortex and the pathophysiological changes were assessed by analysis of the IC responses to stimulation of the sciatic nerve. We recorded the IC responses immediately before and up to 7 hrs. after induction of the ischemic stroke. Based on peri-stimulus time histograms we identified the peak neural response (PNR) for each electrode. Based on the PNR we interpolated the signals to generate 2D neural activity maps for the entire electrode array. To assess the spatial progression of the ischemic stroke over time we calculated two features; 1) the Area, as the fraction of the cortical region that responded to the sciatic nerve stimulation, and 2) the Center of Gravity (COG) of the responding area. RESULTS: Ischemic stroke led to an expansion of the sensory cortical area that responded to sciatic nerve stimulation. The Area kept expanding until 330 min post stroke where an average of 155% increase of activity was reached in comparison to the activity level before stroke, where after it plateaued. The neural response to sciatic nerve stimulation gradually redistributed uniformly around the ischemic core following photothrombosis intervention, since the COG moved towards the ischemic core. CONCLUSIONS: Our observations are in line with the general consensus that the most dramatic phase of damage occurs within the initial hours following ischemic stroke. Our results may provide insight into optimization of new rehabilitation interventions.

S.3. *Muscle mechanics and neural control determining fine hand-motor tasks*

Mechanical factors limiting finger independence

Huub Maas[1], Nathalie van Beek[1], Josien van den Noort[2], Dick Stegeman[3]

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BACKGROUND AND AIM: During several tasks, we need precise movement and/or force control of our fingers. However, the extent in which we can independently control individual fingers is limited. Voluntary movement or force exertion by a single finger is generally accompanied by involuntary movement or force exertion by the non-target fingers. Such limited independence can be attributed to neural and mechanical factors. In this presentation, the focus will be on the latter. Muscle fiber forces can be transmitted to the tendon of non-target fingers via connections between the tendons of the extrinsic finger flexors and extensors. Force can also be transmitted between muscle-heads of adjacent fingers via the intramuscular connective tissue network. Recent studies from our lab strongly suggest that such mechanical constraints play an important role, especially for tasks in which fingers move relative to each other. METHODS: Young healthy subjects performed active single finger flexion through the full range of movement with all other fingers free to move. Kinematics of index, middle, ring and little fingers was measured to assess movement in the non-target fingers and the range of independent movement. Simultaneously, we assessed displacements of the flexor digitorum superficialis tendons using speckle tracking on B-mode ultrasound video's. During flexion of the instructed finger, all non-instructed fingers showed some movement. RESULTS: During flexion of the instructed finger, all non-instructed fingers showed some movement. Most movement was found in the fingers adjacent to the instructed finger. Each finger showed a range of independent movement (between 13% and 61% of the full movement until the tip of the finger touched the palm of the hand),

which was highest for the index finger. The start of non-target finger movement was asymmetrical for adjacent fingers. Finger interdependence was found also at the tendon level. Similar to the joint angle results, initially little or no tendon displacement was found which was followed by a steep increase in tendon displacement. CONCLUSIONS: Our results indicate that no finger can move independently through the full range of finger flexion, but some independent movement is possible for each of the fingers. The range of independent movement both at the tendon and joint level is a result that is in agreement with effects of known mechanical linkages between the muscle-tendon units corresponding to each finger. Although neural factors cannot be excluded, a range of independent movement are less likely the result of neural mechanisms. We propose that mechanical connections between the muscle heads or tendons are initially slack and need a certain relative finger displacement to be pulled taut. The asymmetry of non-instructed movements may indicate a preferential direction of such connections. Funded by EC grant MOVE-AGE.

Neuromuscular control of extrinsic flexors and extensors during single finger movements

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BACKGROUND AND AIM: The human hand is an indispensable instrument essential for performing a large variety of daily actions. When moving one finger the neighbouring fingers commonly move to some extent as well, a phenomenon called enslaving. To understand how finger movements are produced and why they cannot be moved independently, more insight into the neural control of the extrinsic finger muscles is required. The aim of the present study was to assess the activation patterns of finger specific flexor and extensor muscle regions during single finger flexion movements. METHODS: Nine right-handed subjects (22-29 years) performed single finger flexion movements with the hand held palmside up in a 45 degree supination angle. They were instructed to move each finger separately and to not actively resist potential movements of the non-instructed fingers. Muscle activation was assessed using a grid of 90 surface electromyography electrodes (sEMG) placed over the flexor digitorum superficialis (FDS) and the extensor digitorum communis (EDC) muscles. Kinematics of four fingers, excluding the thumb, was recorded using an instrumented glove. Finger specific muscle regions were found by cross-correlation of the EMG envelopes and the angle of the instructed finger. EMG signals were normalized to the maximum EMG amplitude found for each finger throughout all tasks for the flexor and extensor muscles separately. RESULTS: During index and middle finger flexion, the EMG amplitude of the instructed finger flexor muscle region was higher than that of one or more of the neighbouring fingers ($p<0.05$). Only during little finger movements there were no significant differences found between the finger flexor muscles. For the extensor muscles, differences between muscle regions were found only during middle finger flexion, where the EMG amplitude of the middle finger was lower than that of the non-instructed fingers ($p<0.01$). For the non-instructed fingers, most movement was observed in the fingers closest to the instructed finger. This enslaving effect was highest for the ring finger and lowest for the index finger ($p<0.05$). CONCLUSIONS: During finger flexion, not only the FDS region of the instructed finger is activated but some activity is found also in the regions of the other fingers. Some of this flexor activity seems to be counteracted by activation of the specific regions of the EDC. Since our results show that in most cases the non-instructed fingers did move, this coordination pattern is at least partly ineffective. These results indicate that the movements of the neighbouring enslaved fingers cannot be fully explained by the activation patterns of the extrinsic extensor and flexor muscles. This suggests that also mechanical factors, such as tendon interconnections and myofascial force transmission, mediate limited finger independency.

The Effect of the Subsynovial Connective Tissue in the Carpal Tunnel On Finger Motion In Health And Disease

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BACKGROUND AND AIM: Carpal tunnel syndrome (CTS), a compression neuropathy affecting the median nerve at the wrist, is the most common surgically treated problem in the hand, with a prevalence of roughly 3% in the adult population. Aside

from the neuropathy itself, the most common associated finding is fibrosis of the subsynovial connective tissue (SSCT) within the carpal tunnel. While most cases of CTS are considered idiopathic, one hypothesis is that the SSCT fibrosis may cause CTS, by altering the mechanics of tendon and nerve movement, thereby producing the pressure elevation which ultimately compresses the nerve. For the past decade my laboratory has studied this hypothesis, and has produced evidence that SSCT pathology may indeed be a common cause of CTS. METHODS: See citations below for methods. RESULTS: Normally, the SSCT is a filmy multilayer areolar tissue, interspersed among the 9 tendons within the carpal tunnel[1]. As the tendons move, successive SSCT layers are recruited, providing a limit to differential movement of adjacent tendons, beyond that which would be theoretically possible given normal tendon and joint excursions[2]. When the tendon moves beyond this limit the SSCT fails, in both cadavers and animal models[3]. Increasing tendon velocity increases the stiffness of the SSCT and may predispose to injury with more rapid hand movements[4]. In an animal model we have shown that this SSCT damage leads to progressive fibrosis and neuropathy[5], as is seen in human CTS. Clinically, this fibrosis restricts both tendon and nerve motion within the carpal tunnel in CTS patients[6]. Importantly, this impedes the normal ability of the median nerve to 'move aside' when the tendons are loaded, which causes the tendons to translate anteriorly and contact the carpal tunnel ligament. CONCLUSIONS:This observation may explain the pathogenesis of the nerve compression in CTS: the SSCT is damaged by differential finger motion, perhaps from a high velocity repetitive activity; this results in SSCT fibrosis with restricts nerve movement, which in turn facilitates nerve compression and thereby CTS. A finite element model has been developed[7] to help study the effect of various hand movements on SSCT stress and strain, and may help to identify potentially hazardous activities, which may then be modified to reduce the risk of developing CTS. 1. Ettema, A.M., et al., J bone joint surg. American volume, 2004. 86-A(7): p. 1458-66. 2. Vanhees, M., et al., J orth res, 2012. 30(11): p. 1732-7. 3. Yamaguchi, T., et al., J biomech, 2008. 41(16): p. 3519-22. 4. Filius, A., et al., J orth res, 2014. 32(1): p. 123-8. 5. Sun, Y.L., et al., J orth res, 2012. 30(4): p. 649-54. 6. Filius, A., et al., J orth res, 2015. 33(9): p. 1332-40. 7. Matsuura, Y., et al., J biomech, 2015.

Wrist posture and force effects on finger control

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BACKGROUND AND AIM: When asked to move or apply a force with an individual finger, movements and/or forces tend to occur in the other fingers. The anatomical structure of the extrinsic finger muscles suggests that wrist posture may play a role in the involuntary "enslaving effect" (EE) seen in the non-task or "slave" fingers. The rate of motion has been shown to affect enslaving [1], as has changing force levels in isometric contractions [2]. The purpose of this study was to determine the effect of (i) wrist posture on enslaved finger forces during ramp and isotonic exertions, and (ii) the rate of force development on enslaved forces and accuracy. METHODS: Twelve male participants performed 3 submaximal finger flexion and extension actions with the index and ring fingers at 30° wrist flexion, neutral, and 30° wrist extension. Trials consisted of a 5 second isotonic contraction at 25% of maximum, and two ramp contractions. Ramp contractions were performed at 25% MVC/s and 10% MVC/s up to 50% MVC, a 0.5 second hold, and decreased to zero at the same rate. Surface electromyography was recorded from the compartments of extensor digitorum and flexor digitorum superficialis and analyzed at 25% of maximum. Each condition was repeated 3 times for a total of 108 trials. Surface EMG was recorded from each compartment of extensor digitorum (ED 2-5) and flexor digitorum superficialis (FDS 2-5). The EE was defined as the normalized force in the non-task (slave) fingers. Enslaved forces and EMG were analyzed at 25% MVC for isotonic, ascending and descending contractions. Repeated measures ANOVAs were followed up with Tukey's HSD. RESULTS: There was a significant posture x direction x slave finger interaction as seen by greater EE of the fingers adjacent to the task finger in extension exertions with wrist extension. Thus, for extension exertions, enslaving was higher at shorter muscle lengths. There was a significant posture x compartment interaction for muscle activity for extension exertions and flexion exertions of the ring finger, where non-task fingers were significantly more active at shorter muscle lengths. Both rate and phase significantly affected EE for both index and ring finger ramp exertions (all $p < 0.001$). In adjacent fingers, EE was higher with the slower force rate in the descending phase; however, muscle activity was not significantly increased in this phase. CONCLUSIONS: Wrist posture significantly affected enslaving, particularly in fingers adjacent to the task finger in extension exertions at shorter muscle lengths. In these conditions, there was also a concurrent increase in muscle activity across all compartments. The rate of force production and type of contraction (isotonic,

increasing or decreasing force) significantly increased enslaving, without increasing muscle activity. References 1. Kim et al., 2008. Human Movement Science 27; p. 408-422 2. Sanei and Keir, 2013. Human Movement Science 32 (3); p. 457-471.

Correlated deficits in bi-lateral hand function following unilateral stroke

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The impairments in skilled movements of the contralateral hand due to stroke have previously been well characterized. Recent evidence, however, suggests that motor deficits due to stroke are not purely limited to the contralateral hand, with early deficits also being observed in the ipsilateral hand (Noskin et al., 2008). To date, it is unclear whether motor deficits in either hand follow similar time-courses or similar patterns of recovery. Here we show that following a unilateral stroke, individuals do indeed show correlated deficits in skilled finger movements of either hand. Furthermore, these deficits follow similar recovery trajectories over time. 48 first-time ischemic (unilateral) stroke patients and 14 healthy age-matched controls performed a finger individuation task while their behavioral task performance was assessed longitudinally at 5 time points (weeks 1, 4, 12, 24 and 52 immediately after stroke onset). Subjects made individuated force presses with an instructed finger (Fig 1a-b) at four different force levels (20%, 40%, 60%, 80% of MVC), and the patterns of involuntary forces produced by the passive fingers of the instructed hand (enslaving, Fig 1c), and by all fingers of the uninstructed hand (mirroring Fig 1d) were quantified. We found that both the enslaving and the mirroring patterns for either hand were highly reliable within both patients and controls (enslaving, $r = 0.871$, $SE = 0.008$, mirroring, $r = 0.790$, $SE = 0.011$). Furthermore, we found no dominant and non-dominant hand differences for the healthy controls (repeated measures MANOVA, $\chi 2 = 13.9$, $p = 0.17$). A stroke caused an increase in the magnitude of the enslaving, which was restricted to the paretic hand (Fig 2a). Although the enslaving magnitude decreased over time, patients still had higher enslaving in comparison to healthy controls after a year. Similarly, a high degree of mirrored movements on the non-

paretic hand were observed for movements of the paretic hand following stroke. Again, the magnitude of mirrored movements decreased with time but not to the level of healthy controls. Throughout recovery, the enslaving and mirroring magnitudes for movements of the paretic hand were highly correlated, r=0.79, suggestive of a single underlying cortical mechanism responsible for both phenomenon. Finally, while the overall magnitude of enslaving was not increased for both hands, we found that the patterns of enslaving were disrupted similarly across paretic and non-paretic hands. Healthy controls showed stereotypical patterns of enslaving (Fig 3a). After stroke, the enslaving patterns for both hands were similarly disrupted (Fig 3b), and recovered back towards the enslaving patterns for healthy controls. Our findings that the onset and recovery of enslaving and mirroring are tightly coupled, as well as that the enslaving patterns for both hands are similarly perturbed after stroke is highly suggestive of bi-hemispheric cortical reorganization during recovery.

Base vectors in complex finger movements

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Fine hand motor control of the fingers is part of daily activities as grasping and writing. Most common movements involve simultaneous use of multiple fingers, and analysis shows that fingers do not move independently (1). Isolated single finger presses, commonly used to study fine hand motor control, are rare in daily life. Rather, we string together multiple single finger presses into more complex movements as sequences - for example in typewriting -, or we combine a small amount of fingers together - for example forming chords while playing a musical instrument -. How does our brain build a representation of these movements? Does it generate these complex movements as a combination of isolated single finger presses, or is it constrained by muscle synergies? Neural and mechanical constraints may simplify the control of certain movements, but also enforce limitations on single finger mobility. Involuntary force production by non-intended fingers - enslaving -, has been related to both these neural and mechanical factors. On the level of the primary motor cortex (M1), fine finger movements are controlled by the neuronal activity in the hand area. Studies based on multiple methods - microstimulation, transcranial magnetic stimulation (TMS), and functional magnetic resonance imaging (fMRI) - show a lack of isolated somatotopy for the different fingers (2-4). Moreover, it is shown that stimulation of different regions in M1 results in coordinated movements related to natural movements performed on a daily basis (2). The muscle patterns recruited in these movements might limit the possibility of performing arbitrary complex finger movements. This study combines force data of individual fingers with EMG data of both the intrinsic and extrinsic hand muscles. Data is collected during different types of movement: involuntary movement due to TMS on multiple stimulation sites of the motor cortex, and voluntary movement of single finger presses, combined finger presses, and sequences. To investigate whether muscle synergies constrain the way we perform complex movements, the EMG patterns are predicted based on the force data through linear models. The fit of different models, based on the single finger presses and involuntary TMS movement, are compared. Although muscle force and EMG amplitude approximately have a linear relationship, modelling complex movements based on single finger movements reveals non-linearities. These are included in the model through the inclusion of parameters for between-finger interaction. To summarize, our study will show the distributions of EMG activity after stimulating with TMS at different M1 sites as building blocks for the EMG distributions generated during voluntary complex movements. (1)Ingram, J.N., et al. (2008). Exp Brain Res 188(2): 223-226. (2)Overduin, S.A., et al. (2012). Neuron 76(6): 1071-1077. (3)Gentner, R. and J. Classen (2006). Neuron 52(4): 731-742. (4)Ejaz, N. et al. (2015). Nat Neurosci 18(7): 1034-1040.

S.4. *Neuromodulatory Strategies for Improving Motor Control after CNS Damage*

Novel neuromodulation strategies for Parkinson's disease

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Deep brain stimulation (DBS) is an accepted treatment for Parkinson's disease (PD) but its mechanisms of action are not fully understood. Many studies have examined the use of non-invasive brain stimulation such as transcranial magnetic stimulation (TMS) and transcranial direct current stimulation as treatment for Parkinson's disease. The talk will review evidence for abnormal plasticity in Parkinson's disease as revealed by non-invasive brain stimulation and how non-invasive brain stimulation can be used to study the mechanisms of action of deep brain stimulation. Studies that used paired associative stimulation have found impaired cortical plasticity in PD, particularly in patients with levodopa-induced dyskinesia. Dopaminergic medications alone did not restore cortical plasticity in PD patients with levodopa-induced dyskinesia but was restored by subthalamic nucleus DBS together with dopaminergic medications, suggesting that DBS and dopaminergic medications may have synergistic effects. Moreover, subthalamic nucleus DBS increased cortical excitability at specific intervals of about 3 ms and 23 ms after DBS pulse. Cortical plasticity could be induced by repeated pairing of subthalamic nucleus DBS and TMS at these specific intervals. These findings suggest that modulation of cortical plasticity could be a mechanism of action of DBS. Many studies have tested repetitive TMS (rTMS) as a treatment for PD but there are no large, randomized controlled trials to proof its efficacy. Meta-analysis of published studies suggested that high frequency rTMS may benefit PD motor symptoms. A recent randomized controlled trial (MASTER PD study) that involved 61 patients confirmed benefit for motor symptoms with higher frequency rTMS of the bilateral motor cortices but found no improvement in mood symptoms with stimulation of the left dorsolateral prefrontal cortex. Further studies of rTMS for treatment of Parkinson's disease are needed. Many studies aimed to improve DBS as a treatment for PD. These include novel electrode designs that can target multiple brain areas, adaptive stimulation and combination of DBS and non-invasive stimulation. Adaptive or closed-loop stimulation is also being developed. As the clinical status of PD patients fluctuates rapidly, one approach is to measure local field potentials from the target areas that reflect the clinical state of the patient, and then automatically adjust stimulation parameters to optimally treat the fluctuating symptoms to improve the efficacy of DBS. Since repeated pairing of DBS with TMS at suitable intervals can induce cortical plasticity, combined DBS and rTMS may be further explored as a novel treatment.

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Changing a reflex to improve walking: operant conditioning of the soleus h-reflex in people with chronic incomplete spinal cord injury

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BACKGROUND AND AIM: People can learn to change a spinal reflex through operant conditioning (J Neurosci 29: 5784-5792, 2009). Several months of exposure to a reflex operant conditioning protocol modifies specific spinal pathways and can thereby affect behaviors that use these pathways. Previously, we showed that down-conditioning the soleus H-reflex during standing can markedly improve walking in people with spastic hyperreflexia and impaired walking due to chronic incomplete spinal cord injury (SCI) (J Neurosci 2013;33:2365-2375). Based on this success, we are currently testing the hypothesis that H-reflex conditioning during a specific phase of walking can further improve reflex modulation and walking. Specifically, the protocol aims to shape the locomotor reflex activity toward a more normal pattern by reducing the soleus H-reflex size during the swing-phase of walking, where the H-reflex is very small or absent in normal subjects but abnormally large in people with spastic hyperreflexia due to chronic SCI. METHODS: Ambulatory individuals with spastic hyperreflexia are studied with either the conditioning or the control protocol. Conditioning protocol consists of 6 baseline and 30 down-conditioning sessions that occur over 12 weeks (i.e., 3 sessions/week). In each baseline session, the subject completes 3 blocks of 75 control H-reflex trials, in which soleus H-reflex size is measured without feedback. The H-reflex is elicited every other step by tibial nerve stimulation at just above M-wave threshold during the late swing-phase of walking. In each conditioning session, the subject completes 3 blocks of 75 conditioning trials, during which s/he is asked to reduce H-reflex size with the aid of visual feedback. Control protocol consists of 6 baseline and 30 control sessions, throughout which the subject is exposed to treadmill walking without H-reflex elicitation for the number of steps comparable to the conditioning protocol. Before and after the 30 conditioning or control sessions, 10-m walking speed and swing-phase H-reflex are assessed. RESULTS: To date, 10 (5 conditioning and 5 control) subjects with spasticity due to chronic (1-14 yrs) incomplete SCI have participated. In 4 of 5 conditioning subjects, H-reflex down-conditioning was successful; their final swing-phase H-reflex size was 48±18(SEM)% of the baseline value. Their 10-m walking speeds increased by

13±4(SEM)%, and the clonus diminished substantially. In control subjects, the final swing-phase H-reflex size was 155±58(SEM)% of the baseline and the final 10-m walking speed was 100±5(SEM)% of the baseline. CONCLUSION: These results suggest that operant conditioning of the swing-phase H-reflex is possible and can improve walking in people with incomplete SCI. Beneficial effects of swing-phase H-reflex conditioning do not appeared to be caused by just walking. Analysis of locomotor kinematics and EMG to better understand the impact of the swing-phase H-reflex conditioning is underway.

Acute Intermittent Hypoxia Enhances Neuroplasticity In Incomplete Sci

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BACKGROUND AND AIM: Restoration of function after incomplete spinal cord injury relies on three factors. The first is spontaneous recovery, which is progressive and linked to reduction of inflammation and to recovery of neural conduction in damaged spinal circuits. The second factor is the emergence of compensatory strategies in which required movements are performed in different ways from those utilized prior to injury. The third and potentially most appealing approach is the use of neural plasticity as a therapeutic tool in which appropriate neural circuits are reestablished allowing optimal restoration of function. Although neural plasticity has the greatest appeal, it is the most difficult to implement and typically requires extended task repetition, training and practice. METHODS: This presentation will describe an alternative approach, which relies on the administration of acute intermittent hypoxia to persons with incomplete SCI. In this approach, inspired air is switched intermittently to a mixture with sharply reduced levels of oxygen (9.5%). Because the hypoxia exposure is very brief, there is no risk of damage to neural or other tissues, yet the hypoxia can still trigger striking neural plasticity, sufficient to induce tangible improvements in voluntary force generation. This is manifested in performance of standard movements, of the lower extremity (in paraplegic patients) or in the upper extremity in patients with incomplete cervical spinal damage inducing quadriplegia. RESULTS: We have been able to show that brief sequences of intermittent hypoxia (9.50% for 90 seconds, repeated 15 times) for several repeated sequences can produce striking improvements in locomotor function, and in function

of the upper extremity in patients with cervical cord injury. These improvements manifest as changes in gait speed and endurance for the lower extremity, or in strength and dexterity of the upper extremity. CONCLUSIONS: The beneficial effect of hypoxia after spinal cord injury appears to depend upon the existence of hierarchical rescue mechanisms that have emerged through evolution to protect the life of an animal when breathing apparatus or the controlling innervation is damaged. While these mechanisms were historically most visible in the neural control of breathing, they are also applicable in the neural control of limb musculature, and can potentially be harnessed to provide useful therapy in persons with incomplete SCI.

Stimulation-induced plasticity in corticospinal transmission to motoneurones

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BACKGROUND: In humans, the corticospinal pathway provides important input to the motoneurones for the control of timing and strength of voluntary contractions. With stroke or spinal cord injury, corticospinal input can become inadequate to recruit sufficient motoneurones to produce forceful contractions. One way to counteract this impairment in voluntary drive to the motoneurones would be to increase the strength of synapses or number of synapses between the remaining corticospinal axons and their spinal targets. Such changes at a spinal level would mean that the same cortical output would provide more effective input to the motoneurones. Stimulation protocols offer possible ways to influence spinal transmission of corticospinal signals. METHODS AND RESULTS: In the elbow flexor muscles of able-bodied participants, we have shown that paired corticospinal motoneuronal stimulation (PCMS), in which transcranial magnetic stimuli (TMS) are repeatedly paired with maximal motor nerve stimuli at specific interstimulus intervals, can increase muscle responses evoked through stimulation of the corticospinal axons and can also increase the muscle force produced for a given level of descending drive (Taylor & Martin 2009). Increases in responses last for at least 1 hour after 100 pairs of stimuli (Fitzpatrick et al 2016). We postulate that these changes reflect plasticity at the corticospinal-motoneuronal synapses. For the hand muscle, adductor pollicis, 100 pairs of stimuli (TMS paired with ulnar nerve stimuli) resulted in small increases in voluntary activation (4±5%; mean±SD; n=14), measured with twitch interpolation during isometric maximal voluntary contractions. That is, there was a small improvement in the ability of these able-bodied participants to drive the muscle maximally after PCMS compared to after TMS alone. This suggests that changes in the transmission of corticospinal input are effective for high threshold motoneurones as well as those recruited in weak contractions. CONCLUSION: Although PCMS produces reproducible effects in individuals (Fitzpatrick et al 2016) and has shown potential to enhance motor output in people with incomplete spinal cord injury (Bunday & Perez 2012), its effect is not reliable across the population. Therefore, the clinical utility of the technique depends on identification and control of factors that underlie these inter-individual differences. REFERENCES: Bunday KL, Perez MA (2012) Motor recovery after spinal cord injury enhanced by strengthening corticospinal synaptic transmission. Curr Biol 22: 2355-2361. Fitzpatrick SC, Luu BL, Butler JE, Taylor JL. (2016) More conditioning stimuli enhance synaptic plasticity in the human spinal cord. Clin Neurophysiol. 127: 724-731. Taylor JL, Martin PG (2009). Voluntary motor output is altered by spike-timing-dependent changes in the human corticospinal pathway. J Neurosci. 29: 11708-11716.

Using targeted neuroplasticity for rehabilitation

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An operant-conditioning protocol that bases reward on the amplitude of the electromyographic (EMG) response produced by a specific central nervous system (CNS) pathway can target activity-dependent plasticity to that pathway. For example, in monkeys, rodents, and people, an operant-conditioning protocol can increase or decrease the spinal stretch reflex or its electrical analog, the H-reflex. Reflex change begins quickly and then continues at a slow rate over days and weeks. It is associated with neuronal and synaptic plasticity in the pathway of the reflex itself as well as with plasticity elsewhere in the spinal cord and brain. This multi-site plasticity appears to function as a hierarchy, in which the plasticity in the brain guides and maintains the plasticity in the spinal cord that is directly responsible for the reflex change. Because the modified spinal neurons and synapses serve many behaviors, the plasticity produced by reflex conditioning can change other behaviors. In the normal CNS, additional compensatory plasticity prevents the plasticity underlying reflex change from disrupting important behaviors, such as locomotion. In contrast, when CNS trauma or disease (e.g., partial spinal cord injury) has impaired an important behavior such as locomotion, the spinal cord plasticity produced by appropriate reflex conditioning can improve the behavior. Furthermore, in this situation, appropriate reflex conditioning can trigger widespread beneficial plasticity that further improves the behavior. This wider plasticity is hypothesized to reflect a process in which each of the multiple behaviors in an individual's repertoire repeatedly induces plasticity that improves its key features. The aggregate process is a negotiation among the behaviors; they negotiate the properties of the spinal neurons and synapses that they all use. This process maintains spinal cord properties in a "negotiated equilibrium" that serves all the behaviors in the repertoire. The operant conditioning protocol adds a new behavior to the negotiation; the targeted plasticity it produces moves the state of the spinal cord away from its previous location in the multidimensional space composed of the values of all spinal neuronal and synaptic properties. Thus, the new behavior (e.g., a modified H-reflex) can enable the old behavior (e.g., locomotion) to escape an inferior solution (i.e., a local minimum) reached prior to the operant conditioning, and can thereby more nearly restore the key features of the old behavior. Operant-conditioning protocols constitute a promising new therapeutic method that could complement other rehabilitation methods and enhance functional recovery.

Plasticity in the Corticospinal Pathway after Human Spinal Cord Injury

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The corticospinal tract is an important target for motor recovery in humans with spinal cord injury (SCI). Here, I will discuss a novel paired stimulation protocol aiming at enhancing corticospinal transmission and residual voluntary motor output in humans with partial paralysis due to cervical incomplete chronic SCI. Paired-pulse transcranial magnetic stimulation (TMS) of the human primary motor cortex results in consecutive facilitatory motor evoked potential (MEP) peaks in surface electromyography (EMG) in intact humans. These peaks can be used to make inferences about the physiology of indirect (I) waves from surface EMG recordings.

We recently showed that early and late TMS-induced MEP peaks undergo distinct modulation in humans with incomplete SCI, with late MEP peaks likely reflecting a decreased ability to summate descending volleys at the spinal level. Our results suggested that late corticospinal inputs on the spinal cord might be crucial for recruitment of motoneurons after human SCI. In subsequent experiments, we used repeated paired-TMS pulses at interstimulus intervals compatible with a late MEP peak (I3 interval). This protocol resulted in distinct improvements in aspects of corticospinal transmission and voluntary hand motor output in humans with SCI. Thus, specific tailored stimulation of the corticospinal pathway may present a novel therapeutic tool for enhancing voluntary motor output in motor disorders affecting the corticospinal tract.

S.5. ***Joint ISEK-ISB symposium***

Surface Electromyography Meets Biomechanics or Bringing sEMG to Daily Life

Catherine Disselhorst-Klug

Background: Muscles move you! Their coordinated activation is the basis for human movement and locomotion. Impaired muscular activation is not only related to poor movement performance, it causes pain, disability and loss of quality of life. To prevent and to restore movement performance the information about the subject's individual muscular activation is of high relevance. Because of their non-invasive character, the only way to get deeper insight into muscular activation during freely performed movements is related to surface-electromyographic (sEMG) methods. Technological advances have made possible the development of a variety of equipment to monitor muscular activation. Ready-to-use technologies are increasing rapidly driven by technological innovation. They enable sEMG measurements in several new applications such as a part of regular sports training, monitoring, biofeedback in rehabilitation, control of prostheses, etc.. However, the correct interpretation of sEMG signals remains debated even amongst scientists and potential sEMG users are getting lost when applying sEMG technologies especially in new areas of application. No guidance is given for correct application or data processing and interpretation of the results remains questionable. sEMG meets Biomechanics: One aspect complicating the interpretation of sEMG is related to the fact that in most innovative applications dynamic contractions are analyzed. From biomechanics it is well known that the contraction force of the muscle fiber depends on the fiber length as well as on the contraction velocity. Additionally, recent investigations support hypothesis that due to titin the resulting muscle fiber force is higher during eccentric contractions compared to concentric ones. On a more macroscopic level, the torque generated by a muscle depends on its biomechanical moment and with that on the joint position. Since sEMG reflects the number of motor units activated by the central nervous system to reach a certain force level, it is obvious that in dynamic contractions sEMG amplitude as well as its frequency content is affected by the biomechanical parameters mentioned above. Additionally, due to the redundancy of the musculoskeletal system, central nervous activation strategies have to be taken into consideration, which are rarely known in physiological movement control and are hard to manage in pathology. Bringing sEMG Technologies to Daily Live: To take sEMG out from the research laboratory into everyday life and to implement the knowledge about the subject's individual muscular activation into training, treatment and prevention biomechanical as well as neuromechanical aspects have to be integrated in the interpretation of sEMG signal recorded during dynamic contractions. New and innovative sEMG processing, information extraction strategies are needed to bridge the gap between bench and application for sEMG.

Forearm muscle activity differs during gripping in people with tennis elbow compared to healthy individuals.

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Background and aim: Lateral epicondylalgia (LE), commonly referred to as tennis elbow, is a chronic musculoskeletal injury that presents with pain over the lateral elbow that is associated with altered wrist posture during gripping. Although the underlying pathophysiology involves degenerative changes of the common extensor tendon, from which the extensor carpi radialis brevis (ECRB), extensor digitorum communis (EDC) and extensor carpi ulnaris (ECU) muscles originate, their contribution to altered wrist posture and gripping is unknown. Therefore, the aim of this study was to examine the effect of wrist posture on forearm muscle activation patterns during an isometric grip task in people with LE. Methods: Eleven individuals with LE (age range 32 to 65 years, 8 males, 10 right hand dominant) and eleven age- and sex-matched controls were recruited from the community. Surface EMG was collected from ECRB, EDC, ECU, flexor carpi radialis (FCR), flexor digitorum superficialis (FDS), flexor carpi ulnaris (FCU) and anconeus muscles. The tasks in the study were 6 s steady isometric hand grips at 15% of maximal voluntary contraction (MVC) with a neutral wrist posture, 20 degree wrist extension, and 20 degree of wrist flexion. Each muscle EMG amplitude was normalized to the same muscle's peak amplitude during MVC, at each respective wrist posture. Muscle activation was computed as the EMG root mean square in a 25 ms non-overlapping window and averaged from five grip trials at 15% MVC target grip in each wrist posture. Muscle coactivation was calculated as the proportion of each muscle's activity to the net activity of all muscles at each wrist posture. Results: Muscle activation. A main effect of group was detected for overall ECRB activation ($F(1, 20) = 6.22$, $p = 0.021$), where the LE group had significantly decreased activation compared to controls during the 15% MVC target grip force. Pairwise comparisons revealed that LE ECRB activation was decreased in wrist extension ($p = 0.044$) and neutral wrist ($p = 0.043$) posture compared to the controls. Muscle coactivation. A significant main effect of wrist posture was detected for ECRB ($p = 0.048$) and ECU ($p = 0.019$) coactivation, when both groups are combined. However, the post-hoc analyses of wrist posture revealed that ECRB, EDC and ECU coactivation differences ($p < 0.05$) were only present in the healthy controls, with coactivation of forearm extensors unaffected by wrist posture in LE. Conclusion: The results indicate that the forearm muscle activation is altered in LE, most notably in the ECRB which is frequently implicated in this disorder. Absence of significant differences in wrist extensors muscle coactivation between the wrist postures in LE compared to the matched healthy controls indicates the possibility of reduced motor variability due to pain related manifestations of LE. This feature is often seen in other chronic musculoskeletal conditions such as neck-shoulder pain and low back pain.

An electromyographic evaluation of elastic band exercises targeting neck and shoulder pain

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BACKGROUND AND AIM: Specific (Intensive) exercises for the neck and shoulder muscles have been shown to relieve work related pain. To minimize resources for supervision there is a need for simple exercises that are effective and can easily be performed at the workplace during the workday. The aim of this study was to quantify the activity of the neck and shoulder muscles during 6 selected elastic band exercises performed at intensities of 20RM and 12RM. The main hypothesis of this study is that high intensive activation of the neck and shoulder muscles requires specific exercises: Shrugs (SHR) and Reverse flyers (RF) for upper trapezius (UT) activation, Cervical extension (CE) and Lateral flexion (LF) for upper neck extensors (UNE) and Cervical flexion (CF) and Cervical rotation (CR) for sternocleidomastoideus (SCM). METHODS: A group of 11 healthy males (25.9±1.4 years, height 183.6±5.0 cm, body mass 82.1±6.0 kg, BMI 24.3±1.4) with no pain in neck or shoulders (VAS=0) were included. Electromyographic activity was bilaterally recorded from UT, SCM and UNE during the 6 exercises at 12 and 20 RM in randomized order. Electromyographic amplitude was normalized to maximum amplitude obtained during muscle specific maximal voluntary isometric contraction (% MVE). RESULTS: For UT the activity during SHR (100.3±29.8%MVE) and RF (91.6±32.8%MVE) was significantly higher than in the remaining exercises (<20%MVE). For UNE activity during CE (67.6±29.8%MVE), SHR (61.9±16.8%MVE) RF (55.4±16.3%MVE) and LF (45.5±14.6%MVE) was higher than for CR and CF (<20%MVE). For SCM activity was higher during CF (51.7±16.4%MVE), CR (42.5±11.6%MVE), and LF (41.5±14.6%MVE) than during the remaining exercises (<30%MVE). Both SHR and CE produced an activity >60% MVE during 12RM in UNE. Both 20RM and 12RM SHR and RF induced >60% MVE in UT. No exercises induced an activity >60%MVE in SCM. Overall %MVE was during 12 RM about 8-10% larger than for 20 RM. A detailed analysis comparing activity in the concentric and eccentric phases showed higher activity in the concentric than in the eccentric phase, most pronounced for UT. CONCLUSIONS: SHR and FR were highly effective exercises as they induced high muscle activity of both shoulder and neck muscles. These findings have practical implications for the choice

of exercises for workplace suited training programs targeting muscle specific pain and disorders.

Factors affecting smoothness of head movements

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Background: Human head and neck movement is a complex action based on a fine interaction between the musculoskeletal, visual, auditive and vestibular system. An effective movement is typically smooth with one acceleration phase and one deceleration phase. In the presence of pain, the movement may become irregular, with several acceleration and deceleration phases. For persons with neck pain with a traumatic cause, flexion and extension movements are shown to be less smooth compared to controls. The movements were also slower. Are these differences also present in persons with persistent neck pain without a traumatic cause and in other directions? We also examined movement qualities in head rotation to explore if irregularity and slower movements constitute a generalised movement property among these persons. Methods: 14 persons with persistent neck pain and 14 age and gender matched neck pain free controls were included (13 females and one male). All persons trained on the entire test protocol to familiarize with the test laboratory and technical equipment 7-14 days prior to testing. ROM, speed and smoothness were measured during rotations and flexions/extensions based on position data from six motion sensors attached to the head and trunc (Liberty, Polhemus Inc). The persons were instructed to first use their preferred pace, therafter a slow and maximum pace. A generalized mixed-effects model was used for analysis. Results: Persons with neck pain moved their head with a slower self selected pace than pain free controls in both rotation and flexion/extension. They had significantly lower ROM in 5 of 8 movement directions. Using the mixed-effects model, pain status had no impact on smoothness but speed and ROM had (â -0.64 and 0.59 respectively). Trunc movement and tilting of the head out of the main direction during movements, do not affect irregularity (table 1). Rotations were faster than the flexions and extentsions; overall approximately 25% difference (data not given). Increased movement speed and ROM gave more smooth movements (table 1). Conclusions: These preliminary results suggest that smoothness depend on movement speed and

the distance of movement/displacement. All group differences disappeared when controlling for these factors. Therefore, neck pain does not seem to have a principle influence on smoothness. The more jerky movements are due to differences in speed and ROM.

The additional value of electromyography in system identification and parameter estimation to assess the contribution of underlying systems in standing balance

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BACKGROUND AND AIM: Impaired balance is a common complaint reported by elderly due to the degeneration of underlying systems involved in standing balance (i.e. motor system, sensory systems and nervous system) with chronological age, specific diseases and medication use. The involvement of several underlying systems in controlling standing balance and strategies to compensate for each other's deterioration makes it difficult to diagnose the underlying cause of impaired balance. System identification and parameter estimation (SIPE) is an upcoming method to disentangle the contribution of underlying systems in standing balance, which enables early detection of impaired standing balance. In this study, we investigated the additional value of including electromyography (EMG) data of the lower leg muscles in SIPE to reliably estimate the contribution of the underlying systems in standing balance. METHODS: Both simulated data obtained with a comprehensive balance control model and experimental data of healthy young participants were used. A sensory perturbation of the proprioceptive information was applied by rotation of the support surfaces (SS) with a pseudorandom ternary signal with a maximum peak-to-peak amplitude of 1 degree. The dynamic behavior of both the simulation model and healthy young participants were estimated by Frequency Response Functions using system identification representing the sensitivity functions of the ankle torques, body sway and EMG of the lower legs to the SS rotation. A simplified balance control model was fitted on the sensitivity functions to estimate parameters describing the underlying systems with several combinations of the 3

sensitivity functions. For model fits on each combination of sensitivity functions the reliability was described by the mean absolute difference between the estimated values and the values used in the simulation in percentage, by the mean goodness of fit (mGOF) and by the mean relative standard errors of the mean (mSEM) of the estimated parameters. RESULTS: In the model simulations, the results show that including the sensitivity function of the EMG reduced the mean differences between the parameter values used in the simulation and the estimated parameters from 42.65-46.48 % to 7.94-9.33%. Furthermore, the mSEM reduced from 6.924-10.224 to 0.265-0.281. No differences in mGOF were found. Similarly, the results of the fitting procedure on the experimental data show a decrease in mSEM when EMG was included. No differences in mGOF were found between the combinations of sensitivity functions. CONCLUSIONS: Including EMG data of the lower leg muscles in SIPE improves the reliability of the estimated parameters both in simulated and experimental data. Therefore, it is recommended to include EMG in the assessment of the underlying systems involved in standing balance using SIPE to estimate reliable parameters, which gives the opportunity to improve the diagnosis of impaired balance.

Intrinsic foot muscle activity in response to different loading conditions

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BACKGROUND AND AIM: The human foot is an adaptive structure that can conform to the conditions and ground we stand, walk and run on. The foot's complex architecture consists of 26 bones, 33 joints, 107 ligaments and 19 muscles. It is characterised by a prominent longitudinal arch (LA) that compresses and recoils under load, absorbing and returning elastic strain energy [1] through the cycle. Our aims, over a series of experiments, were to characterise how the three largest intrinsic foot muscles, abductor hallucis, flexor digitorum and quadratus plantae are activated in response to different loads and forms of loading, as well as how their activation influences LA compression. METHODS: Vertical loads up to 150% of body weight were incrementally applied to the foot, through the tibia, while recording LA motion and intramuscular electromyographic activity from the foot intrinsic muscles, named above. These muscles were also-involuntarily and independently activated via

indwelling electrical stimulation electrodes while loaded at 50% and 100% of body weight. The spring-like function of the foot and electromyographic activity of the same foot muscles was also assessed while running on a force-instrumented treadmill during shod and barefoot conditions. The latter experiment was performed in response to recent suggestions that running shoes may actually impede LA function, possibly reducing the effectiveness of intrinsic foot muscle function [2]. RESULTS: A decrease in LA height and an increase in foot intrinsic electromyographic activity was observed as the foot was incrementally loaded to 150% body weight. Involuntary electrical activation of the intrinsic foot muscles resulted in a significant decrease in LA compression (increase in arch height) when loaded at either 50% or 100% body weight. All intrinsic foot muscles, as well as muscles of the triceps surae (medial gastrocnemius and soleus), increased their activation when running with shoes as compared to barefoot. The increased muscle activity was accompanied by a reduction in LA compression during the period of maximum loading. CONCLUSIONS: These findings verified our hypothesis that abductor hallucis, flexor digitorum and quadratus plantae have the potential to control foot posture and LA stiffness, particularly during the type of loading that is associated with standing and locomotion. The ability for the foot intrinsic muscles to actively stiffen the arch is likely to have important implications for how forces are transmitted during these types of activities. This is particularly important when running at different speeds, over different terrains and perhaps whether shod or barefoot. For the latter point, our results confirm that running shoes do indeed influence the mechanical function of the foot. Overall our findings support the notion that LA stiffening, through passive and active mechanisms, is important for how forces are transmitted between the foot and ground during locomotion. [1] Ker RF at al (1987) The spring in the arch of the human foot. Nature 325, 147-149 [2] Lieberman DE et al (2010). Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature 463, 531-535

S.6. *Stepping out of the lab: EMG in daily life*

Fully-Integrated Stretchable Epidermal Electronics and Biosensors

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Background Existing classes of electromyography and motion tracking systems have many important capabilities, they lack the mechanical properties necessary for achieving intimate contact, robust signal quality, and maximum comfort for patients. These limitations are due in large part to the bulky and packaged components with terminal connections to wires and rigid circuit boards, which typically do not bend, stretch or adjust with the dynamic curvilinear motions of the human body. Aim A different approach relies on electronics and biosensors configured in ultrathin formats that achieve intimate coupling in ways that are mechanically invisible to the subject [1, 2]. Here we describe new mechanical and electrical design strategies for achieving these medical systems with physical properties that approach that of a soft bandage worn on the epidermis. Methods These 'epidermal electronics' (Fig. 1) are fabricated using flexible electronics and roll-to-roll manufacturing processes using packaged and unpackaged chipsets. The integrated biosensors measure linear motion, angular motion, temperature and electrophysiological activity. Results The sensors and associated circuitry (i.e. microcontroller, memory, voltage regulators, rechargeable battery, wireless communication modules) are all embedded within an ultrathin, highly stretchable elastomeric substrate. Quantitative analyses of system mechanics during cyclical exposure to tensile and bend stresses illustrate the ability of the epidermal electronics to mechanically couple with soft tissues, in a way that is mechanically invisible to the user. These results highlight the soft and stretchable form factor achieved and multimodal sensing, which is ideally suited for monitoring physiological signals from different regions of the body in patients. Conclusions Epidermal electronics provide quantitative biometric information to physicians in a continuous manner over a broad range of clinical applications, with implications for clinical trials and home monitoring. This platform has been validated in the clinical setting and thus serves as a powerful alternative to self-reporting and other conventional clinical screenings.

A Wireless Surface EMG System for Daily Activity Measurement

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BACKGROUND AND AIM: The surface Electromyography (sEMG) is a technique used for recording and extracting neuromuscular information produced by skeletal muscles. During voluntary muscle contractions a number of motor units trigger signal activations which can be detected using sensors placed on the surface of the skin. sEMG is intuitive and convenient in revealing not only single muscle activity, but also the coordination of different muscles during a movement. While sEMG applications in the past mostly focused on clinical studies and rehabilitation, in recent years commercial products that focus on human computer interaction have been emerged. However, most commercially available sEMG systems are limited due to large size, power consumption, and device placement factors. This study presents a portable wireless sEMG system that addresses these limitations and can be used for daily activity measurements. METHODS: The 35mm diameter wireless sensor module presented in this study offers 8 differential sEMG channels and 9-axis motion information. Enclosed in a plastic case (Figure 1), the integrated system is composed of four units: sEMG electrodes, sense electronics, and motion processor and communication unit. Muscle activity acquired by electrodes are amplified and digitized by the sense electronics on the integrated sensor board. sEMG data can be pre-processed on board for noise reduction and transmitted to a processing host using Bluetooth Low Energy (BLE) protocol or a proprietary in house protocol. A host application is developed to configure the wireless sensor and display the data collected by the sensors. The system is powered by a rechargeable coin size battery with a lifetime depending on the sensor configurations. RESULTS: The system was tested by attaching electrodes on a subject's forearm Brachioradialis muscle as differential channels and the subject was asked to perform the hold-fist movements. The electrodes used in this experiment were disposable passive Ag/AgCl solid gel electrodes that carefully skin preparation was required. The raw sEMG data was filtered by a bandpass filter with cutoff frequency 10Hz to 250Hz and a notch filter to eliminate power noise (Figure2 (a)). As a comparison, the same experiment was conducted using a commercial wireless system from Delsys (Figure 2 (b)). The signal-to-noise ratio (SNR) of the signal recorded using the Delsys system and the wireless sEMG system presented in this study are 35.4dB and 37.9dB respectively. CONCLUSIONS: A portable wireless sEMG system for daily activity measurement is developed. The system offers 8 differential channels of sEMG recording and 9-axis motion information. The size of the system provides comfort and mobility. The low power consumption enables long-term recordings without recharging the battery. The quality of the sEMG recorded from the proposed system is comparable to commercially available sEMG systems.

Tattoo-like, long-term electromyography sensors for quantifying muscle fatigue and recovery

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When muscle performance degrades, we need a reliable method to tell whether it is because the subject is not trying hard enough or it is actually due to muscle fatigue. When muscle fatigues, we hope to study its recovery over a time scale of days instead of hours. We therefore manufactured tattoo-like, long-term electromyography (EMG) sensors based on stretchable gold nanoribbons via our newly invented "cut-and-paste" method. The EMG measured by our stretchable electrodes are comparable to the gold standard Ag/AgCl gel electrodes. EMG was gathered by both types of electrodes simultaneously, and the signal-to-noise ratios (SNRs) of the two were found to be within 28.5% of one another. Our ESS electrodes are so thin and soft that they are imperceptible and can be worn for a week. We performed synchronous measurements of EMG from the forearm muscles and hand grip force (HGF) using a NeuLog hand dynamometer once a day over the course of a week without changing the stretchable electrode. Each subject was instructed to grip with maximum voluntary contraction (MVC) for two minutes. For the purposes of our experimental results, fatigue was defined as the degradation of the model with respect to the initial model state. Vectorial autoregressive moving average (VARMA) systems are built to model the relationship between EMG and HGF, and Kullbeck-Leibler criterion is used to track degradation of the model as applied to the Forearm-Hand system with time. The stretchable electrodes combined with the VARMA model clearly shows both a departure from the original model up to a Kullbeck-Leibler of 3, and a return to within 5% of the original model after sufficient resting period. These model changes correspond to changes in forearm-hand dynamics as a result of fatigue.

EMG-based Online Intent Recognition for a Powered Lower Limb Prosthesis

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BACKGROUND AND AIM: Pattern recognition has been used to transition powered leg prostheses between locomotion modes seamlessly. Adding EMG signals to mechanical sensor information improves performance, but is not clinically implemented because signal quality degrades over time. We developed a method for detecting detrimental changes in EMG signal quality by comparing new patterns to a model of previous training data. The aim of this study was to evaluate this technique with amputees using an online pattern recognition system to control a powered knee-ankle prosthesis. We investigated whether our method can prevent errors by reverting to using only mechanical sensors to make predictions when EMG changes are detected. METHODS: Two transfemoral amputees were fitted with a powered knee-ankle prosthesis and completed a protocol that included walking on level ground, ramps, and stairs on two different days. On the first day, an experimenter triggered mode transitions at four gait events (heel contact, mid-stance, toe off, mid-swing). Embedded mechanical sensor and EMG information from four residual leg muscles were recorded during ambulation. Signal features were used to train eight classifiers acting within different modes and at different gait events to predict the transitions between standing, level walking, ramp ascent/descent, stair ascent/descent. Gaussian models of EMG features were developed to inform classifiers when to incorporate EMG into mode predictions. In the second session, an online classifier transitioned the prosthesis between modes. Only mechanical sensors were used if new EMG patterns were significantly different ($>3\sigma$) from the model of EMG features. The percentage of steps where EMG was used is reported for each classifier. Steady-state and transitional classification error rates for each classifier were calculated. The average classifier error for heel contact and toe-off is also reported. RESULTS: EMG signals from the second day were frequently excluded by most classifiers, and none used EMG signals in 100% of its classifications (Table 1). Classifiers operating in standing mode (ST_HC, ST_TO) and the toe-off classifier (TO) incorporated EMG in most classifications. Subjects could successfully transition between modes with low classification error rates (Table 1). The average error rate for all heel contact classifiers was 1.9% [0.9%], (mean [standard deviation]), for steady-

state steps and 5.4% [2.1%] for transition steps. The average error rates for all toe off classifiers was 1.8% [1.0%] for steady-state steps and 0% [0%] for transition steps. CONCLUSIONS: We determined that most EMG signals from the second day contained changes in signal quality. Changes were likely caused by donning/doffing the prosthesis. These variations would normally cause classification errors, but using only mechanical sensors likely kept error rates low. Future work includes creating an adaptive system that can learn to reincorporate EMG.

NeuroGame Therapy for the Improvement of Ankle Control in Children with Cerebral Palsy

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Background: Neural plasticity and motor-learning research suggest that task-specific practice should control intensity, repetition, timing, difficulty, and salience to have the largest effect (Kleim & Jones, 2008). Based on these principles, 'NeuroGame' Therapy (NGT) was designed and has shown promise in upper extremity rehabilitation in children with cerebral palsy (CP)(Rios et al, 2013). We explored the effects of task-specific practice using NGT for improving activation of ankle dorsiflexion muscles in children with CP. Our portable system provided biofeedback from ankle dorsiflexion (ADF) surface electromyography (sEMG). Successful ADF sEMG activation allowed children to control computer games. Study Design: Our repeated measures case series design utilized 5 assessments, each occurring 3 weeks apart. Intervention occurred between the second to the fourth assessment as a home exercise program. Study Participants and Setting: Nine children (3 male) with bilateral lower extremity involvement and spasticity, Gross Motor Function Classification System level I-III, mean 12.15 yrs (SD 3.36 yrs) completed the study. Materials/Methods: Assessments spanned the ICF dimensions including: sEMG co-contraction, standing balance, muscle contraction force (MCF), spatiotemporal and kinematic motion analysis during gait, ADF range of motion (ROM), Selective Control Assessment of the Lower Extremities (SCALE), falls, and the 6-minute walk test (6MWT). Intervention consisted of using NGT 3-5 times per week followed by a 5-minute walking session to practice ADF during gait. Walking adherence was

documented via a FitBit activity monitor. Results were analyzed descriptively case by case. Results: All children used NGT multiple times per week and reported enjoyment of the game. Results were varied based on child, level of involvement, and amount of game play but all children showed improvement in at least two measures. Children who played the game the most showed the most change in sEMG co-contraction during AROM and walking. Positive changes were also seen in balance (6/9 participants) and MCF (4/9 participants). Two children showed improvements with gait (1 dorsiflexion at initial contact, 1 in stride length). Two children had slight increase with walking velocity. Only one child had increased passive ROM. There were changes with the total SCALE scores in 6 of 9 children, and also changes seen with movement quality. Three children improved with their 6MWT. One child had fewer falls. Conclusions/Significance: NeuroGame therapy was feasible and enjoyable for these children with CP, and facilitated repetition and intensity of intervention. Results of NGT use seem to be highly correlated to the amount of time using this device. Participants improved their ADF muscle activity, which lead to some changes in ankle function. NGT, which leverages neuroplasticity and motor learning principles, appeared to increase participants' motivation to perform therapy at home.

Backyard Brains: Using EMGs as an entry into neuroscience education

Gregory Gage[1]

[1]Backyard Brains

Electrophysiology is an exciting and compelling way to engage the public and generate interest in neuroscience research. For the past 5 years my organization, Backyard Brains, has been developing entry-level electrophysiology kits to explore invertebrate nervous systems. Our open source bioamplifiers (SpikerBox) can record and analyze action potentials from the neurons of cockroaches, worms, grasshoppers, and other insects. In this talk, I will discuss our transition to human electrophysiology and it's impact on neuroscience K12 education. Our goal is to create educationally affordable technologies for teaching neuroscience, a subject that has traditionally been ignored in secondary education. By creating exciting and accessible experiments and demonstrations, we aim not only teach neuroscience, but also spark the public's interest in participating in and contributing to neuroscience research.

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DAY 2, THURSDAY JULY 7

S.7. *Synchrony and frequency in neuromuscular control*

Synchrony and frequency in neuromuscular control

Christopher Laine[1]

[1]Univ of Southern California

Significance: In the nervous system, synchrony implies communication or shared input. As such, quantification of synchrony (e.g. among EMG or EEG signals) is an incredibly powerful tool for understanding neural control of muscles. The origin and functional relevance of different types of synchrony have generated continued interest for many years. It is clear that investigating the strength and frequency content of neural drive holds great potential for probing neuromuscular circuitry and control strategies, guiding rehabilitation, and characterizing disease progression. However, we lack a clear conceptual roadmap for the use of these techniques in targeting specific neural mechanisms, and maximizing their utility for scientific and clinical pursuits. Focus: Defining what novel information can be gained about neuromuscular control through measures of synchrony (e.g. correlation, coherence, phase-locking) between signals recorded from humans (e.g. between motor units, EMG, EEG, and kinematic/kinetic measures). Suggested topics for presentation include, but are not limited to: 1) Insights into neural mechanisms of sensorimotor integration, tremor, fatigue, or motor learning. 2) Potential utility of synchrony/coherence measures as biomarkers of motor dysfunction or as relevant measures within the context of rehabilitation technologies. 3) Coordination between muscles and analysis of muscle synergies 4) Relevant statistical/signal processing methods

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Motor control of upper airway dilator muscles

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BACKGROUND AND AIMS: In order to explore the motor control of upper airway dilator muscles, common oscillatory inputs to the motoneurons of genioglossus (GG), tensor palatini (TP) and palatoglossus (PG), were assessed during wakefulness in human participants using coherence analysis conducted on simultaneously recorded pairs of motor units. METHODS: Results are reported for the frequency ranges 0-5 Hz (common drive) and 10-30 Hz (short term synchrony). Electromyograms were recorded via intramuscular fine wire electrodes. In the first study 201 pairs of single motor units were obtained from GG and TP muscles in 24 male participants. In the second study 148 pairs of motor units were obtained from GG and PG muscles in 17 female and male participants. Finally in study three, 77 pairs of GG motor units were simultaneously recorded before, during and after inspiratory loading in 12 male participants. RESULTS: Consistent with an earlier report (Laine & Bailey, J Neurophysiol, 2011, 105, 380-387), study one demonstrated that GG motor units have moderate common drive (coherence in the 0-5 Hz range) and an absence of short term synchrony (coherence in the 10-30 Hz range). But critically, it was shown that the level of common drive was dependent on the discharge pattern of the pairs of motor units; motor units with a respiratory phasic pattern had very high common drive, while motor units that were without respiratory phasic activity (tonic units) had only moderate common drive. Further, respiratory phasic and tonic units did not share common drive (low coherence of respiratory - tonic motor unit pairs). This pattern was replicated in TP motor units and in study 2 in PG units. Of interest was the observation that GG and TP respiratory modulated motor units shared common drive (GG-TP pairs) with the same strength as both GG pairs and TP pairs, while this was not the case for tonic GG-TP pairs. However, unlike GG and TP respiratory phasic motor units, GG and PG respiratory phasic motor units did not share common drive. Finally, in study three we demonstrated that common drive to respiratory modulated GG motor units increased in response to an increase in respiratory drive. CONCLUSIONS: The results suggest that pre-motor inputs differ between respiratory modulated and tonic motoneurons for each of the muscles studied, with respiratory phasic motoneurons showing stronger common drive; this possibly indicates

different functional significance of motoneurons with different discharge patterns. Further, tonic motor units from different muscles did not appear to share pre-motor inputs, while GG and TP respiratory phasic motor units, but not PG units, were strongly influenced by the same pre-motor input. This pattern of activity raises the possibility that respiratory phasic and tonic motoneurons represent different muscle systems with different functional roles.

Investigating neural strategies for muscle coordination

Christopher Laine[1], Francisco Valero-Cuevas[1]

[1]University of Southern California

BACKGROUND AND AIM: Correlated patterns of muscle activity observed during certain actions have often been interpreted as evidence that the nervous system simplifies the task of muscle coordination by controlling them together as a group, rather than independently. It is not always clear if coordination among muscles implies a simplified neural control strategy, an obligatory co-activation, or simply reflects mechanical requirements of a task. Although co-activated muscles often receive some degree of common neural input, it is not clear if/how the strength and frequency content of such input relates to functional control. This talk will briefly cover two lines of investigation in which intermuscular neural drive is characterized under a variety of conditions. In the first (Laine et al., J Neurosci, 2015), we tested the basic assumption that mechanically synergistic muscles are controlled together through shared neural drive, rather than independently. In a second, recent line of investigation, we studied the flexibility of intermuscular neural drive to muscles whose functional coordination depends on task. METHODS: To investigate neural drive to synergist muscles, motor unit activity was recorded from the vastus lateralis and vastus medialis muscles during isometric knee extension. Partial coherence analysis was used to disambiguate the contribution of shared vs. independent drive sent to the motoneuron pools of each muscle, and to track how their relative proportion changes with force magnitude. To investigate neural drive to mechanically separate muscles, surface EMG signals were recorded from the abductor pollicis brevis and the first dorsal interosseous muscles during a variety of two-fingered pinching tasks. These included static and dynamic isometric force generation, the slow rotation of an object between the fingers, and the compression

of a slender spring which requires dynamic, quasi-isometric force modulation to prevent buckling. RESULTS: We found that the two thigh muscles share most of their neural drive, and that the strength as well as bandwidth of this shared drive increase with total knee extension force. In the hand muscles, we found that beta-band (15-30 Hz) intermuscular coherence was reduced when the spring was compressed nearly to the point of buckling, as compared with coherence recorded during the pinching of a wooden dowel at matched forces. Intermuscular coherence during dynamic modulation of isometric force tended to be similar to that observed during static force production. During object rotation, a shared 'Piper rhythm' of ~40 Hz and a 10 Hz common input became dominant. CONCLUSIONS: These investigations demonstrate the flexible nature of intermuscular neural drive, and emphasize that intermuscular synchrony, when measured within the context of an appropriate task, can provide an important window into muscle coordination strategies.

Investigating the neural substrate of motor coordination using muscle networks

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How the central nervous system coordinates the many degrees of freedom of the musculoskeletal system remains an outstanding question. Neural synchronization may offer a novel window into the neural circuitry underpinning motor coordination. Equivalent to its role in perceptual processes, it is suggested that neural synchrony provides a mechanism for integrating distributed motor systems. However, the role neural synchronization has not been systematically evaluated as mechanism for motor coordination. Here I will use complex network analysis to investigate patterns of intermuscular during postural control. EMG from 40 muscles distributed across the body (whole-body EMG) was acquired from 14 healthy participants during upright standing, while postural stability (no, anterior-posterior or medial-lateral instability) and motor coordination (no, unimanual or bimanual pointing) were experimentally manipulated. Intermuscular coherence was estimated between the EMG envelopes of all muscle pairs (780 combinations) and non-negative matrix factorization was used to estimate the coupling strengths that define the edges of the muscle networks. Complex network analysis was used to assess the patterns of neural synchronization and compare muscle networks across experimental conditions. We observed

coherent muscle activity at multiple distinct frequency bands throughout the body. Non-negative matrix factorization revealed four frequencies components centred at 2, 8, 16 and 40 Hz. The lowest frequency component was dominated by connectivity between leg muscles and was affected by postural stability. The higher frequency components revealed more local connectivity that was linked to motor coordination: 8-Hz connectivity in the upper body and arms was observed during the no-pointing conditions while 16-Hz connectivity was observed during unimanual and bimanual pointing. Complex network analysis revealed six modules consisting of (1) bilateral lower leg, (2) left upper leg, (3) right upper leg, 4) upper body, (5) left arm, and (6) right arm muscles. Complex network analysis is ideally suited to analyze the rich patterns of neural synchronization observed between muscles distributed across the body. The significant differences in network topology between experimental conditions suggest that muscle networks are functionally organized. Community analysis revealed six modules corresponding to the major anatomical body parts. By unraveling multiple frequencies components, the contribution of different motor pathways to motor coordination can be investigated.

Motor unit synchronization revisited: Estimating the proportion of common synaptic inputs to population of motor neurons in humans

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BACKGROUND AND AIM: Motor neurons innervating a muscle receive both common and independent synaptic inputs from spinal and supraspinal centers. This observation is classically based on the presence of significant correlation between pairs of motor unit spike trains (Nordstrom et al., 1992). The functional significance of the relative proportion of common input across muscles and conditions is still debated. One of the limitations in our understanding of correlated input to motor neurons is that its robust estimation is still an open problem. Indeed, correlation measures of pairs of output spike trains have several limitations (Negro F & Farina D, 2012; Farina D & Negro F., 2014). In this study, we report a new approach to measure the proportion of common input to a motor neuron pool with respect to the total synaptic input in voluntary contractions in humans. METHODS: We theoretically derived the relation between the common synaptic input and the total amount of

synaptic input received by the motor neuron pool. This analytical derivation is based on a simplified motor neuron behavior (LIF model). Using a least-square curve fitting of the estimated values of coherence for cumulative spike trains, we estimated a parameter (PCI, proportion of common input) linearly related to the amount of common synaptic input received by the motor neuron pool. The new index was tested using a model of 300 realistic motor neurons and on experimental data. Experiments were performed on the abductor digiti minimi (ADM), the tibialis anterior (TA), and the vastus medialis (VM) muscles at moderate force levels. Single motor unit action potentials were recorded with intramuscular electrodes in the three muscles and decomposed using EMGLAB (McGill KG, 2005). RESULTS: In both simulated and experimental results, the estimation of the coherence between pairs of composite spike trains showed a tendency to increase faster for greater levels of input correlation, as predicted theoretically. In simulations, the PCI index showed to be robust and independent on the discharge rates. In the experimental recordings, the averaged (total) number of identified motor unit spike trains for a single trial were 9 ± 2 (45) (ADM), 13 ± 4 (51) (TA), and 8 ± 2 (40) (VM). The estimated values of PCI were 75 ± 12 (ADM), 82 ± 17 (TA), and 63 ± 20 % (VM). These results show that the motor pools of these muscles receive a similar and large (>60%) proportion of common low frequency oscillations with respect to their total synaptic input. CONCLUSIONS: In this study, we have provided for the first time a robust quantification of the proportion of common input to motor neuron pools with respect to the total synaptic input. The results suggest that the central nervous system provides a large amount of common input to motor neuron pools, in a similar way for muscles with different functions and control properties.

Sensitivity of intermuscular coherence to identify common oscillatory synaptic inputs to motor neurons

Kevin Keenan[1], Francesco Negro[2], Dario Farina[2], Roger Enoka[3]

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BACKGROUND AND AIM: Oscillations in the synaptic inputs received by motor neurons have been reported to play a critical role in sensorimotor control. A number of groups are currently developing and improving methods to quantify the

oscillations in common synaptic inputs within and across motor neuron pools and to determine the functional significance of these oscillations. The purpose of the current study was to evaluate the use of coherence analysis between simulated surface electromyograms (EMGs) to quantify common oscillatory synaptic input to two populations of motor neurons. METHODS: Models of two motor-neuron pools were used to simulate surface EMG signals that were detected over both muscles after imposing common oscillatory synaptic inputs across the two motor unit populations. The simulations varied the level of muscle activation, as well as the amplitude and frequency of the common oscillatory synaptic input shared across the two pools of motor neurons. Also, several parameters were varied to examine the influence of crosstalk, motor unit action potential shapes, high-pass filtering, amplitude cancellation, and rectification on EMG-EMG coherence. RESULTS: In general, coherence estimates derived from rectified EMG signals underestimated the level of common input due to the influence of amplitude cancellation and changes in the shapes of the motor unit action potentials. Across several conditions, estimates of coherence obtained from interference EMG signals resulted in a more accurate estimate of the common input than that derived from rectified EMG signals. However, the difference between the two estimates depended on the common input frequency, the cutoff frequency of the high-pass filter, and crosstalk. CONCLUSIONS: As several of these factors above are difficult to assess during experimental conditions, the results indicate that EMG-EMG coherence provides a limited measure of the level of common oscillatory synaptic input received by motor neurons in two muscles.

S.8. *Neuromuscular Electrical Stimulation: Time to Turn the Page*

Maximising the central contribution to electrically-evoked contractions

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BACKGROUND AND AIM: Traditionally it is thought that neuromuscular electrical stimulation (NMES) produces contractions by activating motor axons beneath the stimulating electrodes, thus through pathways restricted to the peripheral nervous system ("peripheral pathways"). However, contractions can also be generated via "central pathways", by the depolarisation of sensory axons beneath the stimulating electrodes which produces contractions via reflex pathways through the spinal cord. The aim of this presentation is to describe how to maximise this "central contribution" to contractions evoked by NMES and provide an overview of the benefits and weaknesses of generating contractions in this way. METHODS: NMES was applied using surface electrodes to produce contractions of the muscles that flex (tibialis anterior) and extend (triceps surae) the ankle. The stimulation was applied over the muscle belly (mNMES) or peripheral nerve trunk (nNMES) using a range of pulse durations (0.05-1.0ms) and frequencies (20-100). Isometric torque was measured using a Biodex system 3 dynamometer. Electromyographic (EMG) activity was measured from the tibialis anterior and soleus muscles. The extent to which peripheral pathways contributed to the evoked contractions was assessed by the amplitude of M-waves in the EMG signal. The central contribution was assessed by the amplitude of H-reflexes and EMG activity that was asynchronous from the stimulus pulses. RESULTS: The central contribution to electrically-evoked contractions was stronger during nNMES than mNMES and, regardless of NMES type, was stronger in the triceps surae than the tibialis anterior. The central contribution was maximised using relatively wide pulse durations. During constant frequency NMES, H-reflexes were depressed but asynchronous activity was greater when high frequencies were compared to lower frequencies. When the stimulation was delivered in a frequency modulated pattern (20Hz for 2s-100Hz for 2s-20Hz for 3s), H-reflexes, asynchronous activity and torque were elevated after the 100Hz "burst" compared to before it. Torque produced via central pathways was less stable than torque produced by peripheral pathways. Contractions generated through central pathways were more fatigue-resistant than contractions produced through peripheral pathways in individuals with no neurological impairment and in individuals with a spinal cord injury. DISCUSSION: Signals travelling along central pathways recruit motoneurons synaptically, according to Henneman's size principle, thus contractions fatigue less than those produced by the depolarisation of motor axons, which is thought to recruit motor units randomly with respect to type. However, the inherent variability of transmission along central pathways makes torque produced by central pathways less stable than that produced by peripheral pathways and the "central contribution" to electrically-evoked contractions can vary widely between muscles and individuals.

Introduction and Conclusion to the symposium "Neuromuscular Electrical Stimulation: Time to Turn the Page"

Nicola Maffiuletti[1], Marco Minetto[2]

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Neuromuscular electrical stimulation (NMES) involves the application of pre-programmed trains of stimuli to superficial skeletal muscles with the ultimate goal to evoke visible tetanic contractions. Unlike other electrical stimulation modalities such as transcutaneous electrical stimulation (that is commonly used for pain relief), NMES-based treatment programs have long been used to either preserve or restore skeletal muscle mass and function during and after a period of disuse due to injury, surgery or illness. The general (quite provocative) idea of this symposium is to present and critically discuss some of the recent advancements that can promote a better clinical application of NMES in the future. Various emerging modalities of stimulation - such as kHz-frequency alternating currents, wide-pulse NMES, peripheral magnetic stimulation, distributed and multipath NMES - have received considerable attention over the last few years, but their principles, feasibility, acceptability and potential clinical effectiveness are not fully understood. For each of these stimulation modalities, the following points will be addressed: (1) functioning principle (how it works, especially with respect to conventional NMES), (2) rationale (why it should be used/preferred - or not - to conventional NMES); (3) effectiveness and clinical acceptability (always with respect to conventional NMES); and (4) population-specific considerations. Our introductory talk will present the rationale and configuration of the symposium, while the concluding talk will provide a summary of key points that will hopefully initiate a constructive discussion.

Predictors of response to neuromuscular electrical stimulation training

Marco Alessandro Minetto[1], Isabelle Vivodtzev[2], Giuseppe Massazza[1], Nicola Maffiuletti[3]

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Neuromuscular electrical stimulation (NMES) represents an effective means for improving muscle weakness in adult patients. However, there is considerable inter-individual variability in response to NMES training, and optimization may relate not only to the parameters of the stimulation paradigm, but also to the characteristics of the subject. The key factor for optimizing NMES effectiveness has been suggested to be the muscle tension which is mainly related to the following stimulation parameters: amplitude of the applied current and frequency of the stimulation busts. Further, recent observations have indicated that the optimization of NMES effectiveness can also be obtained through manipulation of the stimulation paradigm. In fact, the introduction of an interphase interval interposed within the two phases of biphasic pulses enhanced the electrically-evoked contraction force of the quadriceps muscle. In addition, NMES effectiveness is also related to intrinsic anatomical and (patho)physiological properties that should be investigated in stimulated subjects. For instance, individual motor nerve branching, which determines the response of the muscle to the application of electrical current over the skin, should be carefully investigated through the identification of the main muscle motor points. This procedure is essential to establish the proper position of the stimulation electrodes as well as the proper inter-electrode distance, that has recently been found as an important determinant of the torque elicited during electrically-evoked contractions. The proper placement of stimulation electrodes and inter-electrode distance selection enable to maximize the spatial recruitment that is spatially fixed and incomplete during NMES. Another strategy to maximize the spatial recruitment, thus minimizing the extent of muscle fatigue, is to deliver electrical pulses to the nerve trunk. However, as the electrical stimulation of the nerve is not comfortable, a painless approach to stimulate the nerve trunk may be represented by peripheral nerve magnetic stimulation. Consistently, magnetic stimulation of the femoral nerve elicited quadriceps contractions up to 70% of the maximal force and proved to be well-tolerated and effective in improving quadriceps strength and exercise capacity of COPD patients. Further, the following other (patho)physiological factors are thought to contribute to the variability to NMES training: hormonal status, thickness of subcutaneous fat tissue, supraspinal descending drive affecting the balance of inhibition and facilitation of the spinal circuits, changes in muscle excitability. I this talk, we will provide a framework by which to clarify NMES place in clinical practice, by discussing the optimal parameters for a NMES programme and presenting examples of criteria for predicting the response to NMES training that should be used in clinical setting to identify patients most likely to benefit.

Spatially Distributed Sequential Stimulation: Method to Reduce Muscle Fatigue During Transcutaneous Functional Electrical Stimulation

Kei Masani[1], Dimitry Sayenko[2], Robert Nguyen[3], Vishvek Babbar[4], Tomoyo Hirabayashi[5], Austin Berquist[4], Milos Popovic[4]

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Background: One of the limitations with the transcutaneous functional electrical stimulation is the rapid onset of muscle fatigue during repeated and extended contractions. Our team has developed a method called spatially distributed sequential stimulation (SDSS) to reduce muscle fatigue by distributing the center of electrical field over a wide area within a single stimulation site, using an array of surface electrodes. Objective: To extend the previous findings and to prove feasibility of the method by exploring the fatigue-reducing ability of SDSS for lower limb muscle groups in the able-bodied population, as well as in individuals with spinal cord injury (SCI). Methods: SDSS was delivered through four active electrodes applied to the knee extensors and flexors, plantarflexors, and dorsiflexors, sending a stimulation pulse to each electrode one after another with 90° phase shift between successive electrodes. Isometric ankle torque was measured during fatiguing stimulations using SDSS and conventional single active electrode stimulation lasting 2 minutes. Results: We demonstrated greater fatigue-reducing ability of SDSS system compared with the conventional protocol, as revealed by larger values of fatigue index and/or torque peak mean in all muscles except knee flexors of able-bodied individuals, and in all muscles tested in individuals with SCI. Conclusions: Our study has revealed improvements in fatigue tolerance during transcutaneous functional electrical stimulation using SDSS, a stimulation strategy that alternates activation of subcompartments of muscles. The SDSS protocol can provide greater stimulation times with less decrement in mechanical output compared with the conventional protocol.

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An Algorithm for NMES Therapy after Knee Surgery: A Novel Structured Approach

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BACKGROUND AND AIM: We present a two-phase algorithm for patient selection and treatment, which is intended to improve clinical decisions regarding: 1) the appropriateness of NMES therapy, 2) monitoring of patient progress, and 3) the timing and rationale for NMES therapy modifications or cessation in patients with knee surgery. METHODS: The algorithm consists of: treatment phase 1 (first 3 weeks after surgery), evaluation after a week of NMES use, and treatment phase 2 (>3wks after surgery). Ideally, patients are also given a home-based familiarization period consisting of a few days before surgery, which may facilitate better patient tolerance. Following knee surgery for Phase I, we recommend multiple daily bouts (2x/day) of at least 10-15 minutes (15-20 contractions) to maximize exposure when voluntary activation deficits are greatest using stimulation amplitudes set at the highest tolerable level. Relatively long phase durations (e.g. 300 μs) should be used, as wide pulses are more likely to target motor fibers (thus maximizing quadriceps force production), while shorter phase durations (< 100 μs) might preferentially target sensory fibers and contribute to uncomfortable burning sensations during NMES. Frequencies around 50pps are also recommended to maximize force production while limiting early muscle fatigue. We also recommend an on:off ratio of 10:30 seconds, again to maximize exposure while still providing reasonable rest periods between contractions. After the first week of Phase I, patient tolerance to NMES should be evaluated to ensure adequate dose. At a minimum, a full, sustained, tetanic contraction of the quadriceps (no fasciculation observed on visual inspection) should be present with visual or palpable evidence of superior patellar glide. If these criteria are not met, NMES therapy may not achieve therapeutic doses, and alternative rehabilitation strategies should be considered. Patients should be re-evaluated after 3 weeks for the presence of activation deficits to determine if a high-volume, high-intensity approach is still warranted. If activation deficits have largely resolved, a low-volume approach is recommended. Here, the goal is still to supply the quadriceps muscle with high-intensity (high-amplitude) NMES therapy, but with

longer rest intervals between treatment sessions to allow for adequate recovery (e.g., 1x daily or every other day). The only difference in NMES parameters between Phase 1 and Phase 2 is the treatment frequency of application. CONCLUSION: While NMES is most effective in populations where voluntary activation failure is present and most commonly include patients following knee injury or surgery, NMES treatment may also benefit patients with anterior knee pain, knee osteoarthritis or hip arthroplasty.

Low-frequency pulsed currents vs. Khz-frequency alternating currents

Marco Vaz[1]

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Neuromuscular electrical stimulation (NMES) consists in the application of a series of intermittent stimuli to intramuscular nerve branches to trigger visible skeletal muscle contractions. NMES has received increasing attention in recent years because of its potential to serve as a strength training, a rehabilitation, a testing and a post-exercise recovery tool (Maffiuletti et al 2011). Traditional NMES consists of relatively short pulse durations (<400μs) delivered at low to moderate stimulation frequencies (15-40 Hz, low-frequency pulsed current - LFPC) and high stimulation intensities (Collins 2007). LFPC has been used for muscle strength training in healthy and clinical populations (e.g. orthopedic surgery, critically ill and elderly people; Herzig et al 2015). However, it has important limitations (excessive discomfort, limited spatial MU recruitment, high muscle fatigability) that impedes attaining high levels of evoked force. In 2002, Ward & Shkuratova described the pioneer works of Kots et al. (1971, 1977) who proposed a NMES type that was believed to solve some of the abovementioned limitations. Kots et al (1977) claimed that this kilohertz-frequency alternated current (KFAC, 2500 Hz, modulated at 50Hz, later named as Russian current) increased the maximal voluntary isometric contraction (MIVC) by up to 40%. The main reasoning for using KFAC was related to supra-threshold intensities with long-enough duration bursts, capable of producing multiple nerve fiber action potentials per burst that might elicit slightly greater force, smaller discomfort, but an undesirable increase in the rate of fatigue (Ward 2009). The differences in these two types of NMES should produce different physiological responses in terms of torque generation, skeletal muscle damage and discomfort levels. Adayel et al (2011) compared KFAC and LFPC effects on knee extensors torque output, rating of perceive exertion, skin temperature, hormonal responses and muscle damage. They showed similar effects in all parameters between the two NMES types. Silva's et al (2015) systematic review showed no difference on the current evidence between KFAC and LFPC effects on quadriceps-evoked torque and self-reported discomfort levels in healthy subjects. However, Vaz et al (2012) showed that LFPC was more efficient than KFAC to electrically elicited 10% MIVC due to the 15% smaller current amplitude and to the 50% lower perceived discomfort level. Based on the current literature the use of traditional NMES seems to be equal or superior to KFAC. Considering that LFPC stimulators are less expensive and more portable than KFAC stimulators, LFPC may be more advantageous in muscle training and clinical practice (e.g. Vaz et al 2013). However, new studies on the acute and chronic effects of NMES with changes on the existent stimulus parameters: large pulse width, higher frequencies, electrode positioning, and multiple current pathways that might show more encouraging results about LFPC.

O.7. EMG: signal processing

O.7.1 *Optimum threshold for slope sign changes and zero crossing features.*

Rosa Hugosdottir[1], Julie Gade[1], Kevin Englehart[2], Erik Scheme[2], Ernest Nlandu Kamavuako[1]

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BACKGROUND AND AIM: For over two decades, Hudgins' set of time domain electromyography features has been extensively applied for classification of hand motions. The calculation of slope sign changes (SSC) and zero crossing (ZC) features uses a threshold to attenuate the effect of background noise. However, there is no consensus on the optimal value. In this study, we investigate for the first time the impact of threshold selection on classification accuracy, with specific attention to the effect over time. METHODS: Eight healthy subjects participated in the experiment (25 ± 1 years old). Surface EMG was recorded from five channels. Seven hand movements and a no motion class were collected over two separate days with two days in between. Each day, four repetitions were collected for each movement (3s

steady state contractions). The threshold was computed as a factor (R = 0:0.01:4) times the average root mean square of the no motion data. Hudgins' feature set was extracted from signal intervals of 200 ms in duration with 25ms overlap. For each day, classification error (CE) was quantified for each threshold value, including no threshold (CEr0). A subject-based best threshold with associated lowest error (CEbest) was also determined with a four-fold validation procedure. Subsequently, a cross day threshold validation was applied where, for example, CE of day 2 (CEdx) was computed based on the best threshold from day 1 (and vice versa). Finally, the effect of threshold on using training data from one day and test data of the other day was quantified using a two-fold validation across both days. For these purposes, all combinations of R (0:001:4) for SSC and ZC were investigated. RESULTS: On average CEbest (5.26 ± 2.42 %) was better than CEr0 (7.51 ± 2.41 %, P = 0.018), and CEdx (7.50 ± 2.50 %, P = 0.021). Optimising the threshold on day 1 and using it for day 2 (CEdx) provided similar performance (P = 1) as using R = 0 (CEr0). During the two-fold validation between days, the minimum of the average CE was 14.90 ± 3.8 % located at R = 0.06 and 2.18 for SSC and ZC respectively, although not significantly better than CEr0 (16.17 ± 4.05%). Interestingly, when using the threshold values optimized per subject from one day and applying to the other, the CE increased to 19.90 ± 4.6% and 22.86 ± 5.67% for day 1 and day 2 respectively. This is an indication that optimum threshold values do not generalize well. CONCLUSIONS: This investigation suggests that although an optimum threshold can be found, it is highly subject and data driven. This implies that eliminating the threshold for SSC and ZC is a good trade-off between performance and generalization.

O.7.2 *Variability of Features Extracted from sEMG Signal*

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BACKGROUND AND AIM: The use of surface electromyography (sEMG) is promising in a wide range of applications such as muscle condition assessment during ergonomic and sport science studies, diagnosis of neuromuscular and musculoskeletal disorders, assistive device control, and rehabilitation. While it can provide a close look into underlying neuromuscular processes, sEMG is not currently widely used in applications, in part, due to its high inter-individual and test-retest variability in sEMG measurements. Characterizing features extracted from sEMG, both in time- and frequency-domains, have demonstrated high variability between individuals and tests making it difficult to reliably interpret sEMG data. The variability in the measurements of sEMG mean frequency (MF), as one of the most popular frequency-domain features, is investigated in the present work. METHODS: Factors such as statistical estimation error, motor unit number and depth, firing statistics, and conduction velocity, will vary the power spectrum of sEMG and thus the MF measurement variability. It is also known that the sEMG from isometric/isotonic contractions can be considered as a self-stationary signal. However, if such a signal has been observed over a finite time duration, T, estimation error will arise. This is the source which determines the minimum possible MF measurement variability, and thus a baseline for MF variability. Once this baseline has been found, additional variation sources can be added and their effects can be observed. To gain full control of the sEMG being investigated an EMG simulation tool, is used so that the physiological, anatomical and instrumental parameters that might contribute to the variation of the sEMG can be configured. RESULTS: The results of the preliminary investigation show that, the baseline MF measurement variability decreases with increasing signal length T, as shown in Figure 1 for simulated sEMG with parameters set to resemble a bicep brachii during an isometric/isotonic contraction. A similar trend appeared when estimating the MF measurement variance for self-stationary band-limited white Gaussian signals. CONCLUSIONS: These results show that MF measurements must be performed with the knowledge of signal duration in mind. To make MF measurements from signals of different lengths comparable, the relationship between MF variance and T must be considered. The MF measurement variability due to other sources will be reported from theoretical and experimental work.

O.7.3 *Wavelet-based functional ANOVA to reveal statistically-significant contrasts between EMG waveforms recorded in different experimental conditions*

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BACKGROUND AND AIM: We often want to compare the shapes of EMG waveforms that are functions of time, but traditional statistical tests cannot reveal differences

between curves without sacrificing temporal resolution or power. Waveform features identified visually may not be revealed by t-tests or ANOVA applied across time points due to the large number of comparisons. We developed wavelet-based functional ANOVA (wfANOVA) to solve this problem. In wfANOVA, ANOVA is performed in the wavelet domain because differences between curves tend to be represented by a few temporally localized wavelets. Differences are then transformed back to the time domain for visualization. In a previous study, we used standard statistical techniques to identify variation in EMG signals during automatic postural responses to perturbations as the peak acceleration and peak velocity of the support surface translation perturbation were varied (Welch and Ting, J Neurophysiol 2009). The aim of the present work was to compare the ability of wfANOVA and ANOVA performed in the time domain (tANOVA) to identify similar patterns of variation without requiring the experimenter to assume features or time bins a priori. METHODS: We applied wfANOVA and tANOVA to EMG recorded during translation perturbations of the support surface designed so that platform peak acceleration and peak velocity could be varied independently (acceleration: 3 levels; velocity: 4 levels). In wfANOVA, EMG waveforms were transformed to the wavelet domain and analyzed with three-factor fixed-effects ANOVA. Wavelet coefficients with significant initial F-tests ($P<0.05$) were evaluated for significant contrasts across velocity or acceleration levels with post-hoc Scheffé tests. Wavelet coefficients retained after post-hoc were then assembled into wavelet-domain contrast curves and transformed back to the time domain. In tANOVA, an identical analysis was performed in the time domain. RESULTS: In experimental EMG data, wfANOVA revealed the continuous shape and magnitude of significant differences over time consistent with previously described scaling relationships without a priori selection of time bins. However, tANOVA revealed only the largest differences at discontinuous time points, resulting in features with later onsets and shorter durations than those identified using wfANOVA ($P<0.02$). wfANOVA required significantly fewer ($<1/4$; $P<0.015$) significant F-tests than tANOVA, resulting in post hoc tests with increased power. CONCLUSIONS: This work demonstrates that wfANOVA may be useful for revealing differences in the shape and magnitude of neurophysiological signals (e.g., kinematic and kinetic data, EMG, M- and H-waves, firing rates) across multiple conditions with both high temporal resolution and high statistical power. Examples of wfANOVA applications to data including EMG and EEG from other laboratories are also presented.

O.7.4 *Nonnegative matrix factorization to assess spatiotemporal muscle activation*

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Introduction: The distribution of activity can change across a muscle. Such spatial heterogeneity of muscle activity has been assessed by comparing EMG amplitudes between channels within a grid of electrodes [1]. That procedure, however, involves averaging amplitudes over time and, hence, discards temporal information. As an alternative method a k-means clustering has been applied considering both temporal and spatial information [2]. However, this clustering approach requires a priori knowledge of the number of clusters present. Typically this number can only be estimated. If that estimate is incorrect, the clustering may yield an inadequate representation of muscle activity. The aim of the current study was to explore the utility of nonnegative matrix factorization (NMF) in the quantification of temporal and spatial variability of muscle activation. Methods: In eight subjects we measured surface EMG (49±8 electrodes covering the entire biceps brachii) during two contraction types: 1) pure elbow flexion (Fl) and 2) elbow flexion with a superimposed forearm supination (FlSu). The monopolar EMGs were spatially filtered with principal component analysis [3], rectified, smoothened, and normalized to maximum voluntary contraction. We used NMF [cf. 4] to decompose spatiotemporal EMG envelopes into a common signal (CS) and its gain distribution (GD). Furthermore, we quantified the common signal's correlation distribution (CD) and a value describing spatiotemporal heterogeneity by the overall variance accounted for (VAF, Figure 1). Results: VAF was significantly (43%) larger for FlSu than in Fl (89±3% vs. 51±9%). CD showed 28% higher mean, 57% lower standard deviation, and 70% lower mean gradient in FlSu. This hints at less heterogeneity of the spatial activation pattern than in Fl. In contrast, GD showed only a 13% larger mean gradient in FlSu suggesting more variability of the envelopes of closely spaced electrodes over the muscle for FISu than Fl. Conclusion: Our findings render NMF a powerful method for quantifying spatiotemporal muscle activation. NMF does not depend on a priori knowledge of spatial characteristics (e.g. number of spatial clusters), but exploits all temporal and spatial information. The VAF and spatial correlation were sensitive to the contraction type, while the spatial gain represented by GD was not. It can be concluded that the outcomes proposed were sensitive to contraction types and can be interpreted in a physiologically meaningful way. [1] Farina et al., J Electromyogr Kinesiol, 18: 16-25, 2008 [2] Staudenmann et al., J Electromyogr Kinesiol, 19: 882-895, 2009 [3] Staudenmann et al., IEEE Trans Biomed Eng, 53: 712-719, 2006 [4] Lee et al., Nature, 401: 788-791, 1999

O.7.5 *Analysis of amplitude estimation of non-stationary myoelectric signals*

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BACKGROUND AND AIM: Muscle force is highly correlated with the amplitude of the surface electromyogram (sEMG) produced by the active muscle. This relation determines its importance as a feature of myoelectric signals and, hence, the wide spread use ranging from rehabilitation engineering to neuromechanical modeling to artistic performances. Correctly estimating this quantity and understanding its relation to neural drive and muscle force is therefore of paramount importance. The single constituents of the sEMG are called motor unit action potentials (MUAPs). Due to their biphasic nature, concurrent MUAPs are likely to interfere with each other. This phenomenon is called amplitude cancellation and its impact on the sEMG amplitude has been extensively investigated. In this study we first revisit its effect on the standard deviation and continue with an in-depth analysis of various amplitude estimators proposed in the myoelectric signal literature. METHODS: We simulate 10000 Poisson processes and convolve them with realistic MUAPs. We then estimate the standard deviation in case of interference and non-interference (by rectification before summation). The Campbell-Hardy theorem claims the standard deviation to be the same for both scenarios if the following assumptions are met: i) motor unit firing statistics are well described by Poisson processes and ii) a change in their firing rate occurs on a longer time scale (orders of magnitude) than voltage change of single units. We proceed with a comparison of several amplitude estimation techniques. For the comparison we set parameters such that the smoothness of the respective estimates is comparable. The estimation quality is measured in terms of time lag, root mean square (RMS) error and correlation coefficient between the estimate and the imposed neural drive. The tested estimators are RMS, variations of the Kalman filter and a Bayes-Chapman-Kolmogorov (BCK) filter (Sanger2007). RESULTS: As predicted by the Campbell-Hardy theorem we find no difference in estimated standard deviation when interference is compared with non-interference sEMG. When comparing different estimators we find that the BCK filter outperforms other methods. However, we note that the sensitivity with respect to sampling rate of this filter is substantial. Depending on the speed of change of the input signal a higher sampling frequency (~2kHz) might be required to perform better than the much simpler RMS. CONCLUSION: The evidence that the sEMG standard deviation is not affected by the MUAP shape is good news for the estimation of the neural drive. However, this finding stands in contrast with previous findings (Keenan et al. 2005) and, hence, further investigation will need to clarify these sharply contrasting results. The BCK filter proved to be the method of choice when estimating the neural drive, however, its sensitivity to sampling frequency might constrain its use to high-end myoelectric recording devices.

O.7.6 *Automated Detection of Fasciculations in Motor Neurone Disease Patients using B mode Ultrasound: A Comparison with Electromyography*.

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BACKGROUND AND AIM: Motor Neurone Disease (MND) is a progressive, neurodegenerative disease that causes muscle weakness and atrophy alongside involuntary muscle twitches such as fasciculations. The standard method for the detection of the presence of fasciculations is intramuscular electromyography (iEMG). iEMG detects the electrical activation within the muscle tissue that leads to these involuntary twitches. This can be used along with other tests such as nerve conduction, blood tests and MRI to form a diagnosis. However, iEMG is an invasive test, which can cause pain and discomfort for patients. This study investigates the performance of a number of ultrasound image based motion tracking techniques for fasciculation detection and how their performance is affected by different muscles and the orientation of the probe. METHODS: Ultrasound image sequences (35 sec duration, 80fps) and iEMG (48kHz) were collected from Medial Gastrocnemius (MG)

and Biceps Brachii (BB) in 13 MND patients. Longitudinal and transverse images were collected in each muscle, with two videos collected per muscle/probe orientation. Three different algorithms were applied; Kanade Lucas Tomasi motion tracker with mutual information (KLT), Horn-Schunck optical flow (HS) analysis and background subtraction using a mixture of Gaussians (GMM). Performance of each technique, across both muscles and probe orientations, was determined using receiver operator characteristics (ROC). Using the area under the ROC curve, levels of agreement between the iEMG signals and the computer vision were determined. RESULTS: In MG, longitudinal probe orientation gave results of 83.5% (GMM), 80.0% (HS) and 66.8% (KLT). In transverse probe orientation, agreement levels of 82.9% (GMM), 83.4% (HS) and 69.3% (KLT) were found. For longitudinal probe orientation, BB showed results of 83.5% (GMM), 76.2% (HS) and 69.3% (KLT). Transverse probe orientation gave agreement levels of 83.4% (GMM), 75.5% (HS) and 73.0% (KLT). CONCLUSIONS: Results showed good agreement for all muscles/probe orientations when using the GMM twitch detection method. HS performed well in the MG¬ muscle, but displayed a reduction in agreement in the biceps. The KLT had the worst performance throughout. Agreement results tended to be slightly higher in the MG in comparison to the BB, especially for HS, but little difference in agreement was seen between the two probe orientations. Variation between the iEMG and twitch detection signal may be due to large difference in pick-up area between ultrasound (approx.50mm2) in comparison, only the very tip of the needle can detect electrical activity. Therefore, twitches may be viewable in the ultrasound and not in the EMG signal. Overall, computational techniques show promise for automated, objective twitch identification. Further analysis will determine whether these techniques can provide a means to distinguish MND from healthy muscle based solely on fasciculation characteristics.

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O.8. Motor performance and Ergonomics

O.8.1 *The surgeon's workload; traditional laparoscopic (TLS) versus robot-assisted (RAS) surgery*

Bente Rona Jensen[1], Morten Dedenroth[1], Dorte Hartwell[1], Berit Mosgaard[1], Annemette Jørgensen[2], Torur Dalsgaard[1]

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Background & Aim: Musculoskeletal symptoms are common among surgeons performing minimally invasive surgery. Thus, 87 % (1) and 73% (2) of the surgeons who regularly perform traditional laparoscopic surgery (TLS) report work-related symptoms, mainly in neck/shoulder, upper-extremity, lower-back, hand and lower-extremity. TLS is characterized by less motion and more constrained and static postures than e.g. open surgery. Knowledge regarding the potential benefit of robot assisted surgery is lacking. The aim was to study musculoskeletal workload in surgeons during TLS compared to robot-assisted (RAS) surgery procedures. We hypothesized that RAS was less demanding than TLS. Methods: Twelve experienced surgeons (mean age 52 yrs., seniority 20.1 yrs.) performed hysterectomy as TLS and RAS. Each surgeon performed TLS and RAS on the same day (morning and afternoon). TLS was performed in a standing position with visual feed-back to the surgeon from 2D-monitors placed to the side of the surgeon. RAS was performed in a sitting position (Da Vinci SI, Intuitive Surgical System, USA) which allowed forearm and head support. The instruments were manipulated by the fingers and visual feed-back was given through a 3D-monitor on the console. Both types of surgeries were assisted by a colleague. Bipolar surface EMG was recorded bilaterally from neck extensor, upper trapezius and erector spinae (low-back) muscles. EMG measured during surgery was expressed relative to maximum EMG recorded during maximum contractions. Static (p0.1), median (p0.5) and peak (p0.9) muscle activation were calculated. Furthermore, perceived exertion was rated for fingers, wrist, lower arm/elbow, neck, shoulders, low-back and legs before and just after each surgery. Results: Total time for EMG analyses was 2-3 hours for each surgeon. Average neck muscle activity was higher during TLS than during RAS (p0.1: 4.7 vs. 3.0%EMGmax, p0.5: 7.4 vs. 5.3%EMGmax, p0.9: 11.6 vs. 8.2%EMGmax). Average static shoulder

muscle activity was higher for TLS than RAS (p0.1: 5.7 vs. 2.8%EMGmax). These differences were most likely due to available head and arm support during RAS. However, for the low-back higher levels of muscle activity was found during RAS on the dominant side, which emphasize that sitting does not ensure reduced loading of the low-back compared to the standing position. The general trend for the perceived exertion was lower values after RAS than TLS. Perceived exertion for dominant shoulder and legs was higher for TLS than RAS. Conclusion: The surgeons shoulder and neck workload was reduced markedly during RAS procedures compared to TLS procedures. However, prolonged static loading of neck and shoulder muscles still occur during the RAS procedures and individual advices regarding how to optimize sitting postures and working conditions during RAS procedures is therefore recommended. 1.Park, A. et al. J Am Coll Surg 2010;210:306-313 2.Sari, V. et al. Min Invasive Therapy 2010;19:105-109

O.8.2 *Characterizing changes in neuromuscular control in response to different locomotor tasks using electromyographic wavelet analysis*

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BACKGROUND & AIM: The contribution of specific neural systems to human walking is not yet fully understood. Elucidating the sources of neural drive that coordinate walking is important for a fuller understanding of gait disturbance in specific neuropathologies and such may find utility in developing tailored neurorehabilitative therapies for patients. In this study, we characterized changes in sensorimotor movement control in response to altered walking conditions using detailed time-frequency analysis of electromyographic (EMG) signals. METHODS: Bilateral EMG recordings were made over the tibialis anterior (TA) and gastrocnemius medialis (GM) muscles in 28 healthy subjects (age: 50.2 ± 16.1 years; 17 men; 11 women) during normal treadmill walking at half-maximal speed, during dual task walking with a simultaneous cognitive load (Stroop task) and during semi-blind treadmill walking (obscured lower half of visual field). RESULTS: To detect basic changes in neuromuscular activity induced by different walking tasks, we first assessed total rectified EMG intensity of TA and GM for 10% bins of the gait cycle (GC). Total EMG

intensity of TA was significantly modified by the different walking conditions ($p<0.0001$; 2-way ANOVA repeated measures). Post-hoc analysis revealed that TA activity was reduced in the dual task condition during the loading response (1-10%) of the GC (normal vs. Stroop: $p<0.01$). On the other hand, semi-blinded walking led to increased TA activity during the initial phases of the GC compared to normal walking (1-10% of GC: $p<0.001$; 11-20% of GC: $p<0.0001$). In contrast to TA, GM activity showed no overall changes with the factor "walking condition" on the total EMG activity pattern. Post-hoc analysis, however, did reveal significant modifications of GA activity within the mean activity period of the muscle (20-30% of GC; $p < 0.01$). Frequency-domain analysis of the EMG signal using 9 wavelet frequency bandwidths (center-frequencies: 6.9Hz, 19.29Hz; 37.71Hz; 62.09Hz; 92.36Hz; 128.48Hz; 170.39Hz; 218.08Hz; 271.5Hz) during different walking conditions showed that TA activity significantly increased its power within lower frequency bandwidths (spectrum 1: $p<0.0001$; spectrum 2: $p<0.0032$). GM activity showed only unilateral changes in EMG power in the high frequency spectra of the right leg (spectrum 8: $p<0.0009$; spectrum 9: $p<0.0001$). CONCLUSIONS: The preliminary data indicate that different walking conditions lead to altered neuromuscular control of TA muscular activity, with GM activity modified to a lesser degree. Wavelet frequency analysis demonstrated differential power of specific frequency spectra during different ambulatory conditions, which might suggest a change in the neural sources controlling specific walking tasks. Combined time-frequency analysis of the existing EMG data (including neurological patients) will be used to further interpret specific changes in neuromuscular control under different walking conditions.

O.8.3 *Temporal trunk muscle patterns are altered ipsilateral to back injury side despite perception of recovery*

D Adam Quirk[1], Cheryl Hubley-Kozey[1]

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BACKGROUND AND AIM: Altered neuromuscular patterns persist following recovery from low back injury (rLBI)[12]. Redistribution of multifidus muscle activation ipsilateral to the previously painful side includes increased activation of superficial multifidus fibers[1], possibly compensating for unilateral atrophy[3]. This redistribution could alter trunk muscle responses to frontal plane loading, yet current work has only evaluated sagittal plane tasks. This study tested whether neuromuscular alterations are side dependent following recovery of a LBI during a dynamic controlled transfer task. METHODS: Surface electromyograms (EMG) were collected from 24 trunk muscle sites (12 abdominal and 12 back extensors) at 1000Hz from 63 rLBI participants[2] during a series of lifting tasks. Root mean square (RMS) EMG amplitudes were calculated and normalized to maximum voluntary isometric contractions. Raw EMG data were full-wave rectified, low-pass filtered (6 Hz), time normalized to 100% and amplitude normalized to average task amplitude; three trials were ensemble averaged for each muscle. A symmetric lifting task was used to determine RMS differences between multifidus sites indicative of a unilateral >20% or central <10% injury. Eight left rLBI (LrLBI), 8 right (RrLBI) and 8 central (CrLBI) participants were matched (age, sex, mass, height). A dynamic right-to-left transfer task predictably changed the moment acting on the trunk[2] (Figure). Temporal features were captured using principal component (PC) analysis, constructed from ensemble-average waveforms. Mixed model ANOVAs (group, side & muscle) on RMS amplitude and PC scores, were conducted for abdominals and back extensors separately. RESULTS: A group main effect ($p<0.001$) showed abdominal RMS amplitudes in LrLBI were higher than CrLBI, and CrLBI were higher than RrLBI. For back extensors a group*muscle*side interaction ($p=0.04$) captured that LrLBI had higher activation than 3/12 CrLBI and 4/12 RrLBI sites. PC1 captured a differential between RHT and LHT(Figure). For the back extensors there was a group*side interaction ($p<0.001$); RrLBI participants had a greater response to the lateral flexion moment than L&CrLBI, for left sites(Figure). LrLBI experienced a dip in activation (PC3) following lift off for left back extensor sites relative to C&RrLBI, group*side interaction ($p<0.001$)(Figure). CONCLUSIONS: Using multifidus asymmetries to indicate unilateral LBI, the results showed that LrLBI participants inhibit back extensor muscles ipsilateral to their LBI, evidenced by reduced responsiveness to loading, relative to RrLBI (PC1), and an observable dip in muscle activation (Figure). Both patterns reduced activation ipsilateral to the LBI. Yet, participants were recovered at testing suggesting motor learning. Future studies should investigate if these patterns are influenced by pain, or structural impairments. 1) D?Hooge et al, JEK 2013; 2) Hubley-Kozey et al, Work 2014; 3) Hides et al, Spine 1996

O.8.4 ***Computer mouse design and ergonomic mouse pads influence wrist angle, forearm extensor and upper trapezius muscle activity***

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BACKGROUND AND AIM: The computer mouse is used during 31 - 65% of commonly performed computer tasks and is the most widely used human interface device. Non neutral wrist position and wrist and finger extensor muscle activity are thought to contribute to the incidence of wrist and elbow pain associated with computer mouse use. Upper trapezius muscle activity is also associated with musculoskeletal disorders following computer use and can be influenced by the type of mouse used. Given that, ergonomic computer mouse configurations intend to minimise muscle activity and/or maintain neutral wrist angle. The aim of this study was to investigate the influence of 5 different mouse configurations on wrist extensor and upper trapezius muscle activity, and wrist position while performing two standardized mouse tasks. METHODS: Sixteen healthy participants performed two tasks (1) alternating single left mouse clicks between two digital targets and (2) a double left mouse click and drag of an object between 2 digital targets. Five different mouse configurations were used (a standard mouse, a standard mouse with a stationary wrist support, a stationary mouse with a gliding palm support, a vertical mouse and a touchpad). Extensor carpi ulnaris, extensor carpi radialis brevis, and extensor digitorum communis muscle activity was recorded using intramuscular electromyography (im-EMG). Upper trapezius muscle activity was recorded using surface electrodes(s-EMG). EMG data were filtered (band-pass, 4th order butterworth filter, at 20-500Hz for s-EMG, 20-1000Hz for im-EMG) then root mean square (RMS) EMG amplitude (time-constant 0.01 second) was calculated. Data were inspected for artefacts (e.g., high frequency peaks in the EMG signal that could not be accounted for by muscle activity), and 10 mouse clicks (from the middle of the task period) were used for analysis. EMG and wrist position data (±500ms for Task 1, ±1s for Task 2) were averaged around the selected mouse clicks. Muscle activity was normalised to maximal voluntary contractions. Wrist angle (flexion, extension, radial and ulnar deviation) was recorded with an electrogoniometer. RESULTS: Extensor carpi radialis brevis activity did not differ between mouse configurations or tasks ($p>0.71$). Extensor carpi ulnaris activity was greatest when using the palm support and touch pad configurations for both tasks ($p <.02$). upper trapezius activity was greater with

palm support compared to wrist configuration in the single click task (p<0.01). and configurations were associated less extension for both tasks (all p<0.01). radial deviation greatest when using vertical mouse p<0.02) double drag task. conclusions: no simultaneously maintained a neutral position minimized muscle activity. findings offer information that could inform selection of on case-by-case basis.

O.8.5 *Surface electromyographic inter-individual variability and pattern recognition in front crawl swimming*

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BACKGROUND AND AIM: Amplitude analysis of electromyography (EMG) has been used to evaluate swimming technique but the variability of EMG recordings is a complex phenomenon rarely examined in this sport. The purposes of this study were to investigate inter-individual variability in muscle activation patterns during front crawl swimming and to explore if there were clusters of sub patterns present. METHODS: Bilateral muscle activity of rectus abdominis (RA) and deltoideus medialis (DM) was recorded using wireless surface EMG in 15 adult male competitive swimmers during three trials of 12.5 m front crawl at maximal speed without breathing. The median EMG trial of six upper limb cycles was used for the inter-individual variability assessment, quantified with the coefficient of variation, coefficient of quartile variation, variance ratio and mean deviation. Key features, i.e., sections of the EMG curve selected based on their potential to differentiate between muscle patterns and therefore to potentially classify the EMG patterns in clusters of swimmers, were selected based on qualitative and quantitative classification strategies to enter in a k-means cluster analysis. RESULTS: Inter-individual EMG variability in swimming was higher compared to what has been described for other cyclic movements, but when clustering swimmers, variability dropped in all measures with increased levels (clusters) with the exception of variance ratio for left DM (Table 1). Overall variability and variability in the clusters in RA was higher than in DM. In RA, clusters were differentiated by activity in the recovery phase and around the transition of pull to push phase. In DM, distinction was made by activity in the entry phase and during the exit and early in the recovery phase. CONCLUSIONS: Inter-individual variability in a group of highly skilled swimmers was higher compared to

other cyclic movements, which is in contrast with what has been reported in the previous 50 years of EMG research in swimming. In front crawl swimming there is not one general activation pattern for DM and RA, but several sub-patterns are present which are statistically different from each other during specific parts of the stroke cycle, mainly due to differences in amplitude. This leads to the conclusion that coaches should be very careful in using overall reference EMG information to enhance the technique of their swimmers. The present findings suggest that individual characteristics could be of more importance in determining the optimal muscle use pattern with the perspective of increasing performance on one hand or decreasing the risk of injuries on the other hand. The detection of these crucial individual characteristics could be a subject of future studies.

O.8.6 ***Posture variation and maximal acceptable work pace during repetitive work***

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Aim. It is generally agreed that work postures can lead to musculoskeletal disorders in the neck and shoulders. We investigated the extent to which more variation of upper arm postures in a repetitive task influences maximal acceptable work pace (MAWP), muscle activity, and perceived exertion. Methods. Thirteen healthy subjects (6F/7M; age 26 (SD 3) years) performed a repetitive pick-and-place task using their dominant hand in four one-hour conditions. In three conditions the average upper arm elevation was 30°, and the hand was moved (1) horizontally (H30), (2) diagonally with upper arm elevation between 20° and 40° (D20/40), (3) vertically with upper arm elevation between 10° and 50° (V10/50). In the fourth condition, the hand was moved horizontally at 50° average upper arm elevation angle (H50). The travelled distance of the hand was the same for all conditions. Using a psychophysical approach with imposed work paces changing every two minutes (7-13 cycles/min), we arrived at the MAWP of each participant after 50 min. Postures of the arm were recorded throughout, as well as dominant upper trapezius muscle activity. Participants reported their perceived exertion (Borg CR-10) just after each protocol. Results. Kinematic analyses showed that we successfully designed protocols (Figure) differing in posture variation but not in average upper arm elevation angle (H30,

D20/40, V10/50), and differing in average upper arm elevation angle but not in posture variation (H30, H50). MAWP was comparable in the conditions with differing posture variation (10.7 cycles/min), but lower in H50, although not significant (9.3 cycles/min). Subjects worked at MAWP with an upper trapezius activity level that did not significantly differ between experimental conditions (median 54% RVE). Dominant trapezius muscle activity at MAWP in H50 (78% RVE) was higher than in H30 (47% RVE), but not significant. Perceived exertion of the upper arm was higher in H50 (2.5) than H30 (1.5), but also not significant. Figure. Upper arm elevation average angle (left), average angle variation (SD; middle), and average upper trapezius activity (right) at MAWP. Boxplots show median values, 25th and 75th percentiles, and minimum and maximum values across subjects (n=10). Conclusion. Variation in upper arm elevation within the investigated limits did not affect MAWP although upper trapezius activity showed a tendency to increase with more variation. Increased working height tended to increase especially upper trapezius muscle activity and decrease MAWP. Thus, our results indicate that posture variation as applied in the current setting did not lead to significant differences in MAWP or muscle activity variables. More thorough workplace redesigns are apparently needed than those investigated by us to accomplish any major changes in psychophysical outcomes as measured by MAWP. Our results do show that engineers should pay attention to working height when advising companies on work pace.

O.9. EMG: novel applications

O.9.1 *Changes in the surface electromyographic signal during high intensity fatiguing dynamic exercise*

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BACKGROUND AND AIM: Techniques to quantify fatigue in surface electromyographic (sEMG) signals recorded during isometric contractions are relatively well established. However, identifying fatigue in sEMG during dynamic contractions is more challenging. This study aims to examine changes in features of

the sEMG signal recorded during fatiguing submaximal, dynamic exercise to exhaustion. METHODS: Five moderately active subjects, age 25.4±4.9 years, (1 female), participated in this study. Participants were instructed to cycle to exhaustion at a work rate of 161±17 W (approximately 70% VO2peak). Surface electromyography (EMG) was recorded from the rectus femoris, vastus medialis, vastus lateralis, semitendinosus and biceps femoris muscles of the dominant leg using wireless bipolar electrodes (Trigno Wireless System, Delsys, Boston, MA). The root mean square (RMS) amplitude and instantaneous median frequency (Fmed) of a 100ms section centered at the peak of each cycle was calculated for each muscle. The data were divided into bins each corresponding to 5% of the time to exhaustion, and a single average value of RMS amplitude and Fmed were calculated for each bin. These were then normalized with respect to the initial average value. RESULTS: The time to task failure was 4069±1535s. Fmed increased progressively during the trial in all muscles examined. The change in the EMG RMS amplitude and Fmed (averaged over the last 5% of time to exhaustion) for each muscle are presented in Table 1. CONCLUSION: The Fmed of the EMG signal increased progressively throughout the task. This is in contrast to the progressive reduction in Fmed typically observed during a fatiguing isometric contraction. This increase in Fmed may reflect changes in muscle temperature, swelling of muscle fibers, or altered excitability of the muscle fiber membrane in response to high intensity dynamic exercise.

O.9.2 *Feasibility of uterine electromyography outside pregnancy*

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BACKGROUND AND AIM: With an overall effectiveness below 30%, in vitro fertilization (IVF) is in urgent need for improvements, especially in view of the increasing trend towards postponing childbirth in developed societies. Abnormal contraction of the uterus may underlie impaired fertility and unsuccessful IVF. However, currently, there is no method for quantitative assessment of uterine activity and guidance of dedicated intervention. Analysis of the uterine electromyogram (EMG), referred to as electrohysterogram (EHG), has been extensively used in pregnancy for quantifying uterine contractions and could potentially be a valuable support during IVF treatments. In this paper, we preliminary evaluate, for the first time, the use of EHG analysis for characterizing contractions in women outside pregnancy. METHODS: The EHG signal was recorded longitudinally on 10 women with no fertility problems. The EHG was recorded by an 8x8 array of electrodes (2 mm diameter, 4 mm distance) for 4 minutes, during which 2-8 contractions could be expected to occur. On each woman, the EHG was recorded at 4 specific phases of the menstrual cycle, namely, during menstruation, before ovulation, and three and seven days afterwards. Due the hormonal changes it undergoes during the cycle, the uterine muscle is expected to show different behavior in these four phases. Comparison between the extracted feature in the different phases is here evaluated as an indirect validation of EHG analysis. We limited our focus to single channel parameters and estimated the signal energy of a bipolar derivation obtained by the combination of a couple of 2X2 adjacent electrodes selected from the grid. Based on previous studies on the EHG during pregnancy, the energy of the signal was first estimated in overlapping 8-s epochs [1]. In order to retain both frequency and amplitude information, the unnormalized first statistical moment (UFSM) was then selected as the global feature to be extracted from the estimated energy and compared among the recorded phases. A repeated one-way analysis of variance (ANOVA) was performed on this global feature in order to statistically evaluate the comparison. RESULTS: As shown in Fig.1, significantly higher values of UFSM ($p<0.05$) were found during menstruation relative to all the other three phases, when the evaluated feature shows a trend that progressively decreases (not significantly) along the menstrual cycle. CONCLUSIONS: The significant differences shown by the selected feature between the menstruation and the other evaluated phases of the cycle suggest the recorded signals to be representative of uterine activity and motivate further research on the use of the EHG outside pregnancy. Future investigations will explore additional features extracted from the EHG and aim at more direct and quantitative validation strategies. REFERENCES: [1] C. Rabotti et al. , Physiol Meas, vol. 29, no. 7, 2008, pp. 829-41.

O.9.3 *Nonlinear Analysis of Electromyography in Parkinson's Disease During Isometric Leg Extension*

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BACKGROUND AND AIM: Recent studies have employed nonlinear methods, including recurrence quantification analysis (RQA), to characterise dynamical changes of neuromuscular activity underlying motor control [4, 5]. RQA variables, percentage determinism (%DET) and recurrence rate (%REC), have revealed differences in electromyographic (EMG) signals at rest and during isometric contraction in patients with Parkinson's disease (PD) [3]. EMG in PD and healthy controls during unloaded isometric [1] and dynamic [2] contractions of the upper limb has similarly been investigated. Skewness and kurtosis have also been used to examine changes in EMG in PD [1]. The aim of this study was to compare EMG recorded in the upper leg in patients with PD and healthy age-matched controls during loaded isometric contraction. METHODS: Surface EMG was recorded from the extensor and flexor muscles of the upper leg in 15 healthy controls (65 ± 6 yrs.) and 13 PD patients (63 ± 6 yrs.) during isometric knee extension at 15% of maximum voluntary contraction. Each subject performed 4 trials, 25 s duration, against a resistive load at the ankle. A 7.5 s section of each trial was analysed in 1.5 s windows. From time-delayed phase space reconstruction of the EMG signals [7], recurrence plots were estimated to depict dynamic EMG behaviour. %REC and %DET were calculated from the recurrence plots to quantify the level of hidden nonlinear structure in the EMG. Skewness and kurtosis were also calculated to determine the degree of symmetry and "peakedness" about the mean of the probability distribution, respectively. RESULTS: %REC and %DET in the rectus femoris EMG were significantly increased in PD patients, for both left and right legs (%DET: $p < 0.01$; %REC: $p < 0.01$). Kurtosis was also significantly greater in parkinsonian EMG ($p = 0.046$), whereas skewness was not significantly different between groups ($p = 0.076$). CONCLUSIONS: The increased %REC & %DET in EMG of PD patients represents a greater level of structure in the underlying dynamics of the EMG signal [1, 3-5]. %DET indicates repeated hidden patterns over short periods of time. This may be due to increased synchronization of motoneurons, though may also be influenced by other parameters including muscle fibre conduction velocity [3, 4]. Increased kurtosis of PD EMG denotes a greater sparseness of the signal, suggesting periodic behaviour, also consistent with greater synchronization. These parameters which are more pronounced in PD EMG could potentially be employed as biomarkers to aid early diagnosis or monitoring of patient symptoms. REFERENCES: [1] A. I. Meigal et al., J Electromyogr Kinesiol, 19,

2009. [2] S. M. Rissanen et al., IEEE Trans Biomed Eng, 56, 2009. [3] L. Fattorini et al., J Neurosci Methods, 143, 2005. [4] D. Farina et al., J Appl Physiol, 93, 2002. [5] C. L. Webber et al., J Appl Physiol, 78, 1995. [6] M. H. Rose et al., Motor Control, 17, 2013. [7] J. P. Eckmann et al., EPL, 4, 1987.

O.9.4 *Chronic EMG activity reveals early changes in muscle activation in treadmill running SOD1 mice*

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Background and Aim: To improve early diagnosis of amyotrophic lateral sclerosis (ALS), a progressive neurodegenerative disease, we measured EMG activity in hindlimb muscles of SOD1G93A mice. Methods: In contrast to clinical diagnostic measures using EMG, which are performed on quiescent patients, we monitored activity during treadmill running in order to detect presymptomatic changes in motor patterning. Chronic electromyogram (EMG) electrodes were implanted into vastus lateralis (VL), biceps femoris posterior (BFP), lateral gastrocnemius (LG), and tibialis anterior (TA) in mice from postnatal day (P) 55-100, and results were assessed using linear mixed models. Results: Significant effects of SOD1G93A are mainly observed in three parameters: burst amplitude, intermuscular phase, and burst shape (skew). Burst amplitude in BFP is significantly larger in G93A mice, while amplitude in TA and LG increased as in interaction with treadmill incline (TA and LG), and age (LG) in G93A mice. In other words, effects of SOD1G93A on amplitude were significant only when mice ran on an incline, or as they aged. Phase and skew are related parameters that indicate changes in the relative timing of muscle activation during locomotion. In G93A mice, BFP and LG are significantly phase advanced and skew shifts earlier in the burst, while both parameters shift in VL in combination with treadmill incline. Conclusions: These novel results indicate locomotor EMG activity could be used as an early diagnostic tool, and suggest underlying mechanistic changes in the neural control of muscles during disease progression.

O.9.5 *The gluteus medius, gluteus minimus and tensor fascia latae are more active during gait in post-menopausal women with greater trochanteric pain syndrome*

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BACKGROUND AND AIM: Greater trochanteric pain syndrome (GTPS) is a degenerative condition of the gluteus medius (GMed) and minimus (GMin) tendons and the trochanteric bursa that causes debilitating pain over the lateral aspect of the hip and most commonly affects post-menopausal women. Rehabilitation of this condition focusses on strengthening the lateral hip stabilisers (the GMed and GMin), however little is known about the function of these muscle in this population. The aim of this study was therefore to quantify and compare segmental muscle activation of the GMed, GMin and tensor fascia latae (TFL) during gait in post-menopausal women with and without GTPS. METHODS: Bipolar fine wire electrodes were inserted under ultrasound guidance into anterior, middle and posterior GMed and the anterior and posterior segments of GMin in 8 post-menopausal women with GTPS (mean age 58.9, SD 3.3) and 10 female controls (mean age 60.2, SD 2.6). A surface electrode was placed onto TFL and footswitches were positioned bilaterally. A series of 6 walking trials was completed at a self-selected speed in addition to maximum voluntary isometric contraction exercises. All electromyography (EMG) signals were received by a Delsys Trigno Wireless system, sampled at 2000Hz and were processed by high pass filtering, full wave rectification, and further low pass filtering to generate liner envelopes. For each muscle segment, the peak amplitude, average amplitude, and time to peak from each phase of the gait cycle (0-30%, 30%-toe off, total stance and swing) were obtained and compared between groups using independent t-tests and effect size (ES) calculations. RESULTS: Greater average muscle activity in all gluteal muscle segments in participants with GTPS was demonstrated and this was significant at some, but not all, phases of the gait cycle. Peak amplitude and temporal results were less consistent in the gluteal segments. TFL demonstrated significantly higher average (ES=0.84) and peak amplitude (ES=2.23) in the GTPS group only in the swing phase of gait. The EMG burst pattern of anterior GMin in participants with GTPS was reversed when compared to controls; with a larger burst of GTPS anterior GMin activity in early stance and a moderate to large (ES=0.76) difference in average amplitude in the first burst (Fig 1). CONCLUSION: The higher levels of gluteal and TFL muscle activation in response to unilateral loading in GTPS might demonstrate an inability to modulate corticospinal pathway excitability and appropriately grade muscle activity in response to task demands. Recognised in other chronic tendon complaints, this corticospinal driver may contribute to the

recalcitrant nature of this condition. The reversal of GMin burst activity; with a larger first burst and smaller second burst may impact the functioning of this segment as an anterior hip joint stabiliser in terminal extension. The findings of this study may assist with revising rehabilitation protocols for GTPS.

O.9.6 *Quadratus femoris is minimally active in common rehabilitation exercises*

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BACKGROUND AND AIM: Quadratus femoris (QF) is considered one of the most important muscles for hip joint stability. It is morphologically suited to draw the head of the femur into the acetabulum, facilitating hip stability. Dysfunction of this muscle has been associated with a range of hip and lower limb conditions including femoroacetabular impingement, patellofemoral pain syndrome and hamstring associated disorders. Despite its theoretical importance, most of what we know about the function of this muscle is based on cadaveric studies, radiographical imaging and biomechanical modelling. It is difficult then, to prescribe with confidence an exercise program for targeted QF rehabilitation. The aim of this study was therefore to evaluate the activity levels of QF across a range of commonly prescribed lower limb rehabilitation exercises. METHODS: Ten healthy young adults (mean age (range) = 23.8 (22-26) years; females=4) who were active in at least two hours of running related sports per week volunteered for this cross-sectional study. Fine-wire EMG electrodes were inserted into the QF (stance limb) under ultrasound guidance. Retro-reflective markers were secured to pelvic landmarks for the purpose of delineating between exercise phases and repetitions through three dimensional motion capture. Participants performed six repetitions of six exercises (clam, hip abduction, 'running man', single leg squat, single leg bridge, resisted abduction/ external rotation). This was repeated for three sets and the order of testing was randomly assigned. The average EMG activity for each exercise was normalized to percent of maximum voluntary isometric contraction (MVIC) and classified according to previously defined criteria; low (0-20% MVIC), moderate (21-40% MVIC), high (41-60% MVIC) and very high (>60% MVIC). Activity was compared between exercises using a non-parametric repeated measures Friedman's test (α=0.05) and post-hoc

comparisons performed with Wilcoxon signed rank tests ($\alpha=0.05$). To estimate the magnitude of difference in muscle activity between exercises, an effect size was calculated (ES = z-score / √ sample size), where 0.2, 0.5 and 0.8 were considered small, medium and large, respectively. RESULTS: Median activity of all exercises was rated as low, except for clam (moderate, 24% MVIC) (Fig 1). Mean activity was significantly different between exercises ($p=0.05$). Significant differences existed between the following pairs; clam > running man (ES=0.89), clam > abduction (ES=0.77), bridge > abduction (0.74). CONCLUSION: This is the first study to evaluate QF activity in common rehabilitation exercises. The minimal to moderate activity in these exercises is unlikely to provide sufficient stimulus for targeted QF hypertrophy, but could perhaps support use in early endurance or neuromuscular control training

O.10. Sensorimotor control and learning

O.10.1 *Locomotor Adaptation to Stable and Unstable Environments*

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BACKGROUND AND AIM: People use a combination of general and specific strategies to create stable walking. General stabilization strategies (e.g. wide steps) address uncertainty by reducing the nervous system's requirements to appropriately respond to destabilizing perturbations. However, because general strategies are present every step, they inherently limit gait speed and decrease energetic efficiency. In contrast, specific stabilization strategies (e.g. corrective steps) require greater levels of sensorimotor coordination but do not incur the same performance penalties as general strategies. Our purpose was to characterize how individuals adapted stabilization strategies based on environmental uncertainty and available sensorimotor resources. We hypothesized that people would decrease reliance on general strategies when walking in a stable environment, and, increase reliance on general strategies when walking in an unstable environment. METHODS: 8 incomplete spinal cord injury (iSCI) and 10 control subjects performed treadmill walking during three conditions in which external lateral forces were applied to the

pelvis. The conditions were: Null: no forces applied Stabilization: a viscous force field resisted lateral center of mass velocity Destabilization: random impulse perturbations During each condition subjects performed 100 baseline steps, 200 steps in one of the force field conditions and then, all applied forces were abruptly removed and subjects performed 100 more steps to measure any after-effects. RESULTS: Both groups decreased step width and lateral center of mass velocity in the Stabilization field ($p<0.05$). When the Stabilization field was removed, the iSCI group demonstrated large and variable mediolateral movements. Both groups decreased step width ($p<0.05$) during the after-effects period. The average time for step width to return to steady state during the after-effects period was 13 steps, which did not differ between groups ($p>0.05$). Both groups decreased lateral center of mass velocity in the Destabilization field ($p<0.05$). The iSCI group took shorter steps ($p<0.05$) and had a larger lateral margin of stability ($p<0.05$) in the Destabilization field. When the Destabilization field was removed, there were no differences in step width, or lateral margin of stability for either group ($p>0.05$). CONCLUSIONS: Subjects reduced their reliance on general strategies when walking in the Stabilization field. This adaptation persisted when the Stabilization field was removed, resulting in a temporary decrease in lateral stability. In contrast, subjects increased their reliance on general strategies when walking in the Destabilizing field. Potentially, external stabilization could be used in gait training to prime the motor system for learning specific stabilization strategies by decreasing an individual's reliance on general strategies. Supported by the Department of Veterans Affairs, CDA2 #1 IK2 RX000717-01.

O.10.2 ***Hybrid Robotic System for Reaching Rehabilitation after Stroke***

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Aim: To validate the feedback error learning algorithm implementation to adjust the functional electrical stimulation (FES) intensity when it is combined with a passive upper limb exoskeleton to rehabilitate reaching movements in stroke. Method: One female chronic stroke patient with a hemorrhagic stroke (37 years old, right-handed, 13 months of evolution post-injury) participated in two experimental sessions. The subject was donned with a passive upper limb exoskeleton (to compensate the arm?s weight against gravity) and with two FES electrodes placed over the anterior deltoid and triceps muscles (to assist the shoulder flexion and elbow extension movements respectively). The experiment consisted in performing reaching movements with the affected arm following a reference presented on a screen in front of the patient. In session 1, patients performed 6 runs consisting of 8 movements each plus an additional run of three movements without FES assistance. In session 2, 8 runs plus an additional unassisted run were carried out. The reference trajectory was generated using the minimum jerk trajectory function. The arm position was estimated using the information of the resolvers embedded in the exoskeleton. We implemented two independent controllers (assuming that the movement of the forearm and upper arm were independent of each other). These controllers modulated the pulse width of the electrical stimuli, which in turn adjusted the delivered assistance. The implemented FEL controller was composed of a PID controller with an integral anti-windup strategy as feedback controller. The feedforward loop relied on a neural network (NN) learning the inverse dynamic of the system. Results: Fig 1 shows the summary of the results obtained. The two figures on the left depict the average RMS error for each run during day 1 (blue) and day 2 (red) for the shoulder (column 1) and elbow (column 2), respectively. The best-fitting linear regression line was calculated considering both the error of day 1 and day 2, which results in a slope of -0.491 (shoulder) and -0.715 (elbow). This negative slope is associated with the decreasing trend of the error as more task repetitions are performed (thus reflecting the learning of the controller). The figures on the right show the differences between completed movements with and without FES assistance. It can be observed the inability of the user to follow the reference without FES assistance (red line). Conclusion: The system is capable of learning the inverse dynamics of the controlled system and, using this information, it can reduce the error trajectory as the patient repeatedly rehearses the movement during the rehabilitation. The system assists in such way that it only provides the required assistance to allow the patient to complete successfully the task. Furthermore, its learning capability allows the system to compensate the variability of musculoskeletal responses to FES across time. Future work will test the effectiveness of the system as a rehabilitation tool. Figure 1. (Left): averaged RMS error for each run during day 1 -blue- and 2 -red-. The black line represents the

trend of the error. (Right): movements performed in session 2 with and without FES assistance compared to the reference trajectory.

O.10.3 *Size of kinematic error affects retention of locomotor adaptation in children with cerebral palsy*

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Introduction: Gait impairment is the one of the most common abnormality in children with Cerebral Palsy (CP), and limited walking ability causes negative effect on their daily life [1]. Previous studies indicated error augmentation induced by force perturbation might accelerate motor learning during locomotor training [2]. However, it remains uncertain whether the size of error and the variability of error have an impact on the retention of locomotor adaptation. We hypothesized that the size of error but not the enhanced variability of error would have impact on the retention of locomotor adaptation in children with CP. Methods: Eleven children with CP aged 8-16 years old, were recruited to participate in this study. Three types of force perturbations (i.e., abrupt, gradual and noisy loads) were applied to the right leg above ankle starting from late stance to mid-swing in three test sessions while subject walked on a treadmill. Leg kinematics and EMG signals from 8 leg muscles were recorded using a customized 3D position sensor and surface electrodes, respectively, during treadmill walking [3]. Results: We observed that children with CP adapted to force perturbation and showed an aftereffect consisting of increased stride length after load release for the conditions with abrupt and gradual loads. Further, we observed a longer retention of aftereffect for the condition with gradual load than that with abrupt load. We observed no aftereffect for the condition with noisy load. Conclusion: Results from this study suggested that the size of error might have impact on the retention of locomotor adaptation of children with CP with longer retention for the condition with small size of error than that with large error. In addition, increased variability of error had a detrimental effect on locomotor

adaptation. This finding suggests that applying a gradual perturbation load during locomotor training may facilitate retention of locomotor adaptation in children with CP. [1] Rosenbaum P., et al., Developmental Medicine and Child Neurology Supplement, 109: 8?14,2007 [2] Amy J. Bastian, et al., J Neurophysiology, 103: 2275-2284, 2010 [3] Wu M. et al., Experimental Brain Research, 216: 473-482, 2012

O.10.4 ***Motor learning with pain results in long-lasting changes in motor strategies***

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BACKGROUND AND AIM: Although sports and rehabilitation programs often involve training in the presence of pain, the effect of pain on motor learning and retention remains unclear. Studies in rats suggest that pain causes learning deficits lasting longer than the duration of nociceptive input, but human studies report conflicting results. The aim of this study was to assess how experimentally induced muscle pain affects motor performance and muscle activation strategies in humans when learning an arm-reaching task in a novel force field environment. METHODS: Eleven participants performed forward reaching movements with the dominant arm using a robotic handle. Participants could not see their moving arm; instead, a mirrored LCD screen provided real-time feedback of hand position. One hundred movements were performed in each of six conditions: Baseline 1, Baseline 2, Force Field 1, Washout 1, Force Field 2, Washout 2. During ?Force Field? trials, the robot applied a velocity-dependent force to the hand, perpendicular to movement direction. Muscle pain was induced in the anterior deltoid muscle of six people immediately before both Baseline 2 and Force Field 1 by injection of hypertonic saline (HYP), whereas isotonic saline (ISO) was used as a pain-free control for five people. Task performance was assessed by the mean orthogonal force applied against the walls of a force channel in force field trials, and by the mean orthogonal position error. EMG was recorded from biceps (BB) and triceps brachii (TRB), anterior (aDEL) and posterior deltoid (pDEL) with surface electrodes, and the EMG envelope was averaged across movement duration. RESULTS: Task performance was similar between groups across all conditions and epochs (no significant main effect or interactions with Group, all $p > 0.1$). However, several group differences were found in EMG amplitude (Group*Condition interactions, all muscles $p < 0.05$). Following the first injection

(Baseline 2), aDEL EMG was lower in the HYP than ISO groups ($p = 0.001$). After the second injection (Force Field 1, Washout 1), EMG was lower for all muscles in the HYP than ISO groups (all $p < 0.05$). EMG remained lower after pain had dissipated (Force Field 2, Washout 2, all $p < 0.001$), except for BB EMG ($p > 0.07$). CONCLUSIONS: Despite pain related to injection of HYP into aDEL, participants in both groups achieved a similar performance during perturbed arm reaching movements, suggesting that pain does not prevent the acquisition of a new motor task. However, the muscle activation strategy adopted by the HYP group to complete the task involved reduced activity of agonist and antagonist muscles, which might reflect an attempt to reduce the stress in the painful area. Remarkably, a similar strategy was used during re-exposure to the same perturbation in the absence of pain. Reduced EMG potentially provides short-term benefits (e.g. decreased muscle stress), but also long-term consequences (e.g. reduced joint stability).

O.10.5 ***Neck pain: Do head movement qualities change during an intensive treatment period?***

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Background: Musculoskeletal pain is one of the most common reasons to seek contact with the health service world wide. It causes great pain and reduced function for the individual and great coasts for society. Neck pain is one of the most common musculoskeletal pain sites. Altered movement qualities such as range of motion (ROM), speed and smoothness is associated with neck pain. However, it is unknown how these dysfunctions changes with treatment and whether these functional properties change in parallel with the self-reported pain and neck function. Methods: 13 persons (11 females/ 2 male) with persistent neck pain aged 43.6 years (SD 9.0yrs) were included in a multi-disciplinary rehabilitation programme for 7-11 weeks. Patient reported data and movement qualities during voluntary head movements were collected at inclusion and end of the period. ROM, speed and smoothness were measured during movement in the horizontal and the vertical plane based on position data from six motion sensors attached to the head and trunc (Liberty, Polhemus Inc). The persons were instructed to first use their preferred pace, therafter a slow and maximum pace. Results: At inclusion, the NDI ranged from 18 to 66 %,

and average pain last week from 1 to 8 (NRS 0 - 10). The group had a NDI score of 36.3% and average neck pain last week 4.6 (SD 2.4). ROM, average movement speed and smoothness increased through the rehabilitation period both for rotation and flexion. The increases were significant for the preferred and slow pace in both directions for ROM, speed and smoothness (exept slow pace flexion). The reduced smoothness is most likely linked to the increased speed. Conclusion: These preliminary results suggest that although no specific attention was directed towards movement qualities in the rehabilitation programme, the patients improved in these variables. They choosed to move at a faster self preferred speed after the treatment period. This will be explored further.

O.10.6 *Multichannel SEMG activity and force variability during isometric contractions at low level forces in diabetic individuals*

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BACKGROUND AND AIM: The aim of this study was to investigate if diabetic neuropathy progression resulted in changes on (i) lower leg muscular activity and (ii) force variability during low level isometric contractions. METHODS: Ten control subjects (49.4±9.6yrs) and 39 diabetic patients (59.4±5.0yrs; 13.7±10.1yrs of diabetes diagnosis; 209.7±88.2mg/dL blood glucose) participated. The participants were assessed for (i) vibratory perception (128Hz turning fork), (ii) tactile sensitivity (10g Semmes-Weinstein monofilament) and (iii) presence of typical neuropathy symptoms. These three groups of variables were used as linguistic inputs in a fuzzy system to classify the neuropathy degree (score 0-10). Multichannel Surface EMG (64 electrodes matrix: 15x4, OT Bioelettronica) was acquired during 10, 20 and 30% of maximum isometric voluntary contractions (MVC) of tibialis anterior (TA) and gastrocnemius medialis (GM). TA was evaluated during dorsiflexion and GM during plantar flexion, both performed with knee in full extension and ankle in neutral position. Contractions were performed for 10s and the central 5s (2.5-7.5s) were analyzed. Force levels were measured by means of strain gauges mounted on an ankle ergometer. The 2D maps of RMS were obtained from the SEMG recordings.

RMS values were normalized with respect to the mean RMS obtained over 0.5s epoch during MVC tests. After normalization, the mean RMS and maximum RMS values were obtained from each SEMG map. Standard deviation (SD) and sample entropy (SaEn) were calculated from force signals to assess mean force, as well as the amount and structure of variability. Correlation analyses were performed to investigate the association between RMS (mean, max) or force variables (SD and SaEn) and neuropathy degree ($p<0.05$). RESULTS: There was no correlation between any of the RMS variables and the neuropathy degree suggesting that there are no changes in the level of muscle activation during low level contractions due to the disease status. During 30%MVC plantar flexion, there was a trend for a higher force variability with the progression of neuropathy (SD: $p=0.053$, $r=0.285$) while force SaEn diminished with neuropathy degree ($p=0.013$, $r=-0.359$). During dorsiflexion at 10%MVC force, variability increased with neuropathy progression (SD: $p<0.01$, $r=0.389$) and SaEn tended to diminish ($p=0.082$, $r=-0.257$). We also found a tendency towards higher variability with neuropathy progression when subjects performed dorsiflexion at 20%MVC (SD: $p=0.083$, $r=0.256$). CONCLUSION: Although no differences were observed in the RMS, the observed changes in the amount and structure of the force variability suggest that the neuropathy progression affects motor control, especially for dorsiflexion, that is mainly controlled by TA muscle, and during lower level forces, indicating that a different muscle pattern of activation might be present.
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O.11. Novel measurement techniques

O.11.1 *High density multi-channel needle electromyography: towards electrical cross-sectional imaging of human skeletal muscle*

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Background and Aim: The distribution of muscle fibres is altered in various neuromuscular diseases. Electromyographers attempt to infer this 2-dimensional fibre distribution from the motor unit potential (MUP), a 1-dimensional voltage versus time signal recorded from a single recording surface at the tip of the needle [1]. This is highly subjective, and diagnostic accuracy is relatively poor [2]. Alternative techniques, eg scanning EMG can provide greater detail but are extremely time consuming to perform. We aimed to develop a clinically-applicable EMG system capable of rapidly determining muscle fibre localisation. Methods: We describe a novel electromyography system comprising a micro-fabricated parylene-C flexible electrode incorporating 64 recording surfaces each of 25μm diameter. These are arranged in two linear arrays, with an electrode spacing of 400μm but offset by 200μm to produce a zig-zag pattern. The electrode is 400μm wide and 20 μm thick allowing it to be bonded to a conventional 30G EMG needle for human recordings. To decompose the data into the constituent MUPs, we designed an iterative algorithm: the channels are first sorted based on their signal to noise ratio. The data from the channel with the highest SNR are clustered (using principal component analysis and Gaussian Mixture Model) and the MUP with highest amplitude is selected and subtracted from the rest of the channels. This process is repeated until no more MUPs are detected. The identified MUPs are then averaged and independent component analysis is used to decompose the MUP into fibre potentials. A Support Vector Machine classifier (trained on simulated data) is then employed to filter the ICA results and return the most likely number of fibres and their mixing coefficients. The mixing coefficients are then used to localize the fibres by fitting an approximated model of the fibre potential. Results: From a single needle insertion, we were able to characterise up to 8 motor unit cross-sections from normal human tibialis anterior and biceps brachii muscles from 30 second recording epochs. These motor unit cross sections showed median firing frequencies of 5.5 to 8.8s-1, and durations of 5.4 to 12.7ms. The length of the motor unit cross sections varied between 1.0 and 6.4mm. Our fibre localisation algorithm allowed the localization of individual muscle fibres within these motor units with a distance error of less than 200μm on simulated data. Conclusion: Our system allows the simultaneous recording of multiple motor unit electrical cross-sections from a single needle location. The ability to localise individual muscle fibres within these motor units promises a major step forward in clinical EMG diagnosis. [1] Whittaker RG, Practical Neurology 2012;12:187?194. [2] Dardiotis E, et al. Acta Myol. 2011 Jun;30(1):37-41.

O.11.2 ***Spatiotemporal muscle activation of a sustained contraction until task failure assessed with nonnegative matrix factorization***

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Introduction: Changes in the spatial distribution of muscle activity have been observed during fatiguing contractions [1]. The procedure often involves averaging amplitudes over time and thus discarding temporal information. An alternative method is to apply k-means clustering to both temporal and spatial information [2]. However, this clustering approach requires a priori knowledge of the number of clusters present. To avoid this requirement we here explored the utility of nonnegative matrix factorization (NMF) in the quantification of spatiotemporal heterogeneity of muscle activation during a contraction sustained to task failure. Methods: Surface EMG signals (49±8 electrodes covering the entire biceps brachii) were recorded in 8 subjects during a sustained elbow flexion at 30% maximal voluntary contraction (MVC) force until task failure. The monopolar EMGs were spatially filtered with principal component analysis [3], rectified, smoothed, and normalized to obtain EMG envelopes over three 10 s time windows (Figure 1). The mean and variability of force and mean EMG envelopes were assessed. NMF [cf. 4] was used to generate a value that described spatiotemporal heterogeneity of the EMG envelopes by the amount of explained variance (VAF). VAF was also assessed for detrended EMG envelopes in order to determine the influence of the monotonic increase (linear fit in %MVC/s) within each time window on the NMF outcome. Results: Subjects sustained an elbow flexion force of 94±12 N for 5.6±2.4 min. There was a significant increase in force variability (2-5 N, $p<0.001$) and EMG amplitude (16-45%MVC, $p<0.001$). The VAF of the original EMG envelopes did not change during the fatiguing contraction (~54%, $p=0.197$), whereas VAF increased over the three time windows (35-48-59%, $p=0.002$) for the detrended EMGs. The increase in EMG activity within each time window showed an overall positive trend

0.33±0.65%MVC/s with no significant effect due to time ($p=0.32$). In contrast, the variability of the increase in EMG activity significantly increased across the three time windows (0.14-0.26-0.59% MVC/s, $p<0.001$). Conclusion: NMF can quantify spatiotemporal muscle activity and does not depend on a priori knowledge of spatial characteristics (e.g., number of spatial clusters). The VAF was sensitive to the monotonic increase in muscle activity, as indicated by an increase in homogeneity for the detrended EMG envelopes. The increase in force variability during the sustained contraction was accompanied by an increase in muscle activity [cf. 5] and appears also to involve a rise in the variability of the monotonic increase between channels over the muscle with fatigue. [1] Farina et al., J Electromyogr Kinesiol, 18: 16-25, 2008 [2] Staudenmann et al., J Neurophysiol, 11: 984-990, 2014 [3] Staudenmann et al., IEEE Trans Biomed Eng, 53: 712-719, 2006 [4] Lee et al., Nature, 401: 788-791, 1999 [5] Enoka RM, J Biomech, 45: 427-433, 2012

O.11.3 ***Monitoring changes in motor unit behavior following short-term high intensity interval training with high-density surface electromyography motor unit tracking***

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BACKGROUND AND AIM: High intensity interval training (HIT) has been widely used to improve fitness and aerobic capacity. Although many studies have evaluated the short term metabolic and cardiopulmonary benefits of HIT, there are no studies investigating changes in neuromuscular function. We aimed to study the behavior of motor units (MU) after HIT. In particular, we evaluated the feasibility of using MU decomposition from high-density surface electromyography (EMG) recordings and tracking the decomposed MUs using cross-correlation of MU action potentials (MUAPs). METHODS: Six healthy men (29 ± 3 yr; 178 ± 7 cm; 80 ± 7 kg) performed six HIT training sessions over two weeks. Each session consisted of 8-12 x 60 s

intervals at 100% peak power output (352± 55 W), separated by 75 s of recovery. Pre and post intervention, participants were asked to perform maximal (MVC) as well as submaximal (10, 30, 50 and 70% of MVC) isometric knee extensions. EMG was recorded from the vastus lateralis (VL) and medialis (VM) muscles using grids of 64 electrodes. EMG data from the submaximal contractions were decomposed to obtain the firings of individual MUs using the convolution kernel compensation algorithm. Finally, and in order to track the different MUs, identified firings were used to trigger surface EMG signals by creating a MUAP profile for each MU which was then matched by cross correlation (CC). MUs that presented a CC > 80% were considered to be the same unit. Functional parameters such as peak torque (Nm), rate of force development (RFD), time-to-task failure as well as EMG amplitude (average rectified value; ARV) and individual MU characteristics (average and peak discharge rate and MU conduction velocity) were compared pre and post intervention by paired t-tests (α=0.05). RESULTS: Peak torque significantly increased after the intervention by 7% (217.8 ± 57.7 to 233.9 ± 49.4 Nm, p=0.02).This was accompanied by a significant increase in ARV at all submaximal contraction levels and at MVC, for both muscles (p<0.05).No changes in RFD and time-to task failure were observed (p>0.05). From VM and VL a total of 94 and 84 MUs were identified respectively. On average, 46.8% and 42.9% of the MUs identified by decomposition could be tracked pre to post intervention, for the VM and VL, respectively (average CC= 84.7± 0.7%). MU conduction velocity significantly increased for both muscles at all submaximal force levels, while the average and peak MU discharge rate significantly increased at 30, 50 and 70% MVC (p<0.01) for both muscles. CONCLUSIONS: Two weeks of HIT produced a significant increase in strength and changes in MU behavior. In particular, increased muscle activation as well as increased MU discharge rate were observed. Interestingly, these changes were greater among higher threshold MUs, which could be due to the higher loads used for HIT. The present study is the first to succesfully track MUs after a training intervention.

O.11.4 *Neuromuscular control adaptations in strength trained athletes: a high-density EMG study*

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BACKGROUND AND AIM:Whilst early neuromuscular changes elicited by strength training protocols in unaccustomed subjects have been extensively studied, little is known about the long-term effects in chronic strength trained athletes. The aim of the study was to test the hypothesis that chronic strength training results in specific changes in motor unit recruitment strategies. METHODS: Nine strength trained athletes (CST, age 23 ± 2 years, height 181 ± 9 cm, weight 86 ± 7 kg, mean ± SD) and eight moderately active controls (CO, age 23 ± 2 years, height 177 ± 3 cm, weight 70 ± 6 kg, mean ± SD) were enrolled in the study. Subjects were asked to follow a trapezoidal ramp trajectory by isometrically activating the elbow flexor muscles. Trajectories consisted of three different segments: 1) force-up phase from 0% to 70% MVC; 2) steady state phase at 70% MVC lasting 10 s; 3) force-down phase from 70% to 0% MVC. Rate of force increase/decrease was set at 5%MVC s-1, 10% MVC s-1 and 20% MVC s-1. Order of ramps was randomized and a convenient recovery time between attempts was allowed. High-density surface electromyography (HDsEMG, 128 electrodes) was recorded from Biceps Brachii muscle of the dominant arm. Global HDsEMG variables in both time and frequency domain (muscle fibre conduction velocity, MFCV, median frequency, MDF, and root mean square, RMS) were computed. Global MFCV, MDF and RMS were normalised for their maximum value at MVC. Area under the curve (AUC) from the MFCV, MDF and RMS values was calculated during each phase. RESULTS: Maximal isometric torque was significantly different (CST vs CO: 103 ± 17 vs. 62 ± 7 N*m; $p < 0.001$, mean ± SD), MFCV at MVC was higher for the CST cohort (4.82 ± 0.17 vs. 4.54 ± 0.28 ms-1, $p < 0.05$, mean ± SD). In Figure 1 data for 5%MVC s-1 ramp are reported. Both absolute and normalised MFCV (AUC values) for the ST cohort were higher during all the ramp contractions and ramp phases ($P < 0.001$). Normalised MDF (AUC) and RMS (AUC) were not significantly different during any ramp contraction ($P > 0.05$). CONCLUSIONS: Chronic strength training might elicit specific adaptations at the motor unit recruitment strategies. The ramp up-phases during the fastest and the slowest ramp contractions showed an increase in the range of motor unit recruitment for the CST subjects (i.e. higher upper limit of motor unit recruitment). However, the general control scheme is preserved.

O.11.5 ***Assessing somatosensory evoked potentials using high density surface electromyography grids***

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Aim. Somatosensory evoked potentials (SSEPs) have been recorded for the interest of evaluating spinal conduction during maturation[1], monitoring spinal cord function during spinal surgery for scoliosis[2], and identifying SSEP components in the upper limb[3]. Previous research involved invasive peripheral nerve recordings via needles, invasive oesophageal probes inserted through nostrils, and non-invasive spinal recording overlying spinous processes from L5 to C6^{4,5,6}. We aim to detect neuronal activity at spinous processes L4 and L5 with high-density surface electromyography (HD-sEMG) grids after electrostimulation of the N. Tibialis Posterior. Methods. Ten subjects (6F/4M) participated in the study. Subjects were lying in a prone position while being stimulated at the N. Tibialis just posteriorly of the Lateral Maleolus via two large square electrode pads (Dura Stick). A pseudorandomised protocol of 1,000 stimulations (0.2 µs duration; 3 Hz frequency) was applied on both the left and right side and repeated two times. Two HD-sEMG grids (8×8 electrodes with 4.0 mm inter-electrode distance) were attached laterally from spinous processes L4 and L5, bipolar EMG at the sternum (ECG response). A common ground electrode was placed on the Lateral Condylus of the recording site. All signals were sampled at a rate of 2,048 Hz along with the digitally converted pseudorandomised stimulations. We high-pass filtered signals offline (10 Hz, 2nd order Butterworth) and removed ECG artefacts using principal component analysis⁷. Epochs were temporally aligned and averaged to obtain SSEPs at each of the 128 recording sites. Results. The Figure displays the results of a typical subject, 128 temporally aligned SSEPs of both the left and right side. Signals are displayed from 6ms onwards, due to a delayed response at the spinal cord level. Regions particularly activated are both upper lateral sides, so mainly spinous process L4. The visible SSEPs are a summation of afferent neuron activity, not distinguishable into different afferent nerve fibres with the current equipment. Figure. Bilateral SSEPs recorded with HD-sEMG at vertebrae L4 and L5; arrows indicate positive (P) and negative (N) electrophysiological components (ms) of the nervous activity travelling wave. Conclusion. Our data show that HD-sEMG equipment may serve to reliably detect motor neuron activity at spinous processes L4 and L5. The signal-to-noise ratio appears sufficient but a higher sampling rate is needed to distinguish different afferent neuron types contributing to the response signals. We consider HD-sEMG promising for future (clinical) research as a non-invasive method for detailed localisation of afferent nervous activity at the spinal cord level from peripheral electrical stimulation. References. 1 Cracco et al. 1979; 2 Macon and Poletti 1982; 3Rossini et al. 1981; 4 Desmedt and Cheron 1980; 5 Desmedt and Cheron 1981; 6 Desmedt and Cheron 1983; 7 Willigenburg et al. 2012.

O.11.6 *Design of New Multi-channel Electrodes for the Collection of Surface Electromyography Monopolar Signals for the Software Generation Signals for Linear Array and Laplacian Configurations for Digital Signal Processing*

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The aim of this research was to design and build a new multi-channel electrode, which is able to obtain more in quantity and refined data from muscle signals. The acquisition of surface electromyography signals from a selected muscle was to be executed using this multi-channel electrode. The first part of this research covered the design aspects that are required to be considered when developing a new multi-channel electrode. The new multi-channel electrode has eleven pins to collect monopolar signals, which are separately configured in a software that represent linear array and Laplacian configuration. The design specification of the new pre-amplifier ideally was to have a gain of 500 and a band-pass filter between 5 Hz and 1 kHz. The final design of the pre-amplifier circuit uses an INA 118 instrumentation amplifier which was built and tested to give values for gain of 501 with a band-pass filter of 6.8 Hz and 1.02 kHz. The new electrode with the pre-amplifiers was built and used for acquiring monopolar signals vastus lateralis muscle of the legs quadriceps from ten healthy participants. The participants performed a 50 % maximum voluntary isometric contraction until complete fatigue of the muscle. Using the five central monopolar signals, a linear array configuration was generated in the software to give either four single differential or three double differential signals. A three-channel Laplacian configuration was generated using all of the eleven monopolar signals. These new signals generated from both configurations were used for extracting features using signal processing techniques. The signal processing technique used was an overlapping window technique that extracts the features of mean frequency

(MNF) and median frequency (MDF) for each window of the Fourier transform power spectrum. Other features extracted for each window were the root mean square (RMS) values of the signal and the muscle fibre conduction velocity (MFCV). The configuration which gave more useful and refined results was the Laplacian rather than linear array. The results of the Laplacian configuration showed that the MNF, MDF and MFCV showed similar trend lines, where they remained at steady values between 20-30% and 70-80% of the signals analysed, after which they fell to 15-30% of this value. The RMS trend line showed a linear increase in value throughout the signal.

O.12. Motor Units II

O.12.1 ***Comparison of Five Methods for Estimating Motor Unit Firing Rates from Firing Times***

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BACKGROUND: The central nervous system (CNS) regulates recruitment and firing times of motor units to modulate muscle tension. Understanding firing rate modulation provides insight into the CNS, in both health and disease. Estimation of the firing rate time series is typically performed by decomposing the electromyogram (EMG) signal into its constituent firing times, then lowpass filtering the constituent train of impulses defined by the firing times. Little prior work has quantitatively examined the performance of different estimation methods, particularly in the inevitable presence of decomposition errors. The study of electroneurogram (ENG) and electrocardiogram (ECG) firing rate presents a similar problem, and has applied novel simulation models and firing rate estimation techniques. METHODS: We adapted an ENG/ECG simulation model to generate realistic EMG firing times derived from known rates, and then assessed various firing rate estimation methods. Five different rate estimators were studied: the instantaneous rate, Hanning window filtering of the impulse train of firing times

(DeLuca et al., 1982), rectangular window filtering of the impulse train (Berger et al., 1986), the spline interpolation method of Mateo and Laguna (2000) and a (simpler) direct spline interpolation method. RESULTS: The ECG-inspired spline-based rate estimators worked exceptionally well when EMG decomposition errors were absent, but degraded unacceptably with decomposition error rates of 1% and higher. Typical expert EMG decomposition error rates are 3-5%. At realistic decomposition error rates, the instantaneous rate consistently exhibited higher errors than either of the Berger and DeLuca methods--so long as the optimal window duration was selected for these methods. When firing rate was modulated as a sinusoid, the Berger method (with optimal window durations selected) exhibited lower error than the DeLuca method, but only at the lowest modulation frequencies evaluated (0 and 0.25 Hz). However, the DeLuca method may have produced lower error had its window duration been permitted to extend beyond our maximum evaluated duration of 800 ms. When firing rate was modulated randomly over a 1 Hz bandwidth, the DeLuca method (with optimal window durations selected) exhibited lower error than the Berger method. CONCLUSION: Overall, each of the Berger and DeLuca methods performed well, so long as the optimal window duration was selected. Our results provide a mechanism for selecting the optimal window length for these methods, based on the characteristics of the modulation in firing rate for a particular application. Optimal window duration for the Berger and DeLuca methods decreased as modulation frequency increased, as average firing rate increased and as decomposition error rate decreased. References Berger, Akselrod, Gordon, Cohen. IEEE Trans Biomed Eng 33:900-904, 1986. DeLuca, LeFever, McCue, Xenakis. J Physiol 329:129-142, 1982.

O.12.2 ***The common synaptic input signal underlying the common drive***

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BACKGROUND AND AIM: The nervous system appears to regulate the strength of relatively steady muscular contractions by modulating the firing rates of all the active motor units in parallel. This process is often referred to as the "common drive." We attempted to estimate the common synaptic input to the motoneurons that produces this parallel modulation. METHODS: We used multiple electrodes and EMG

decomposition to extract the firing patterns of up to 36 concurrently active motor units during steady contractions of human arm muscles. We estimated the synaptic input to each motoneuron using a simple model in which the motoneuron membrane voltage depends on the afterhyperpolarization and the synaptic input. This approach produced a scatter cloud of discrete points, with each point indicating the estimated synaptic input to one motoneuron at one of its firing times. An example is shown in the figure. RESULTS: In each contraction, the scatter cloud of points followed a common trajectory, showing that the synaptic input to each motoneuron consisted of a common signal plus synaptic noise. The common signal had most of its power below 10 Hz, and it produced motoneuron membrane fluctuations as large as 20% of the afterhyperpolarization amplitude. This common input signal was responsible for the parallel modulation of firing rates throughout the motoneuron pool. CONCLUSIONS: The synaptic input signal of each motoneuron is the sum of signals from multiple descending and peripheral sources. The fact that each motoneuron receives essentially the same net synaptic input signal implies that the various presynaptic signals are homogeneously distributed throughout the motoneuron pool. Because of this homogenous distribution, the motoneurons are modulated in parallel and the motoneuron pool as a whole acts as a single dimensional system, computing and transmitting a single regulatory control signal to the muscle.

O.12.3 ***Assessment of single motor unit activation in central and peripheral neuronal disorders***

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INTRODUCTION: Neuromuscular diseases represent a large group in the field of movement disorders. The malfunction of muscles can have its origin in the lower or upper motoneurons. An example for affected upper motoneurons is spasticity after stroke whereas in spinal muscular atrophy (SMA) lower motoneurons are affected. The symptoms of these neuromuscular diseases vary from muscle weakness to increased muscle tone and therefore the question arises whether there is an impact to muscular activation on the basis of different motoneurons. In this study the cerebral activation of single motor units of patients with spasticity and spinal muscle atrophy are compared. METHODS: The activation of single motor units is assessed noninvasively with high-spatial-resolution-electromyography (HSR-EMG). The HSR-EMG is the combination of a multi-electrode array and a two-dimensional Laplace-filter and enables a noninvasive recording of single motor unit activity. The abductor pollicis brevis muscle was measured at maximum voluntary contraction. Three groups took part in this study, the first one made up of ten patients with spasticity after stroke, the second of one nine patients with spinal muscle atrophy and the last group of eight healthy subjects. Several parameters, including general signal parameters like root mean square, entropy and number of peaks per second and peak parameters like firing rate and variation of peak amplitude, were calculated and compared for the analysis of the activation patterns. RESULTS: Root mean square had the lowest value for spastic group, the results for SMA group and healthy subjects were quite similar. Entropy was highest for healthy group and showed lower values for spastic group and SMA group. The healthy group had the highest variation of peak amplitudes; it was less for SMA group and lowest for spastic group. The number of peaks per second was highest for healthy group, less for SMA group and lowest in spastic group. The firing rate of isolated motor units was lowest and with little deviation in spastic group. In contrast the firing rate was similar for SMA group and healthy group whereas in SMA group the deviation of the firing rate was higher. CONCLUSION: The results show that, depending on whether upper motoneurons or lower motoneurons are affected, motor units are activated in specific activation patterns. The activation pattern in spinal muscular atrophy is similar to healthy muscles although, due to the loss of motor units, to a lesser extent. In a spastic muscle the number of activated motor units is also decreased. However, the firing frequencies are low and very constant. The combination of this activation pattern and symptoms like stretch reflex hyperexcitability points to an autonomous activation mechanism. The regulating effect of the brain is absent due to the affected upper motoneurons and the result is a self-excited activation of single motor units controlled by the spinal cord with an own natural frequency.

O.12.4 ***Modulation of motor units serving different VM fibers during knee extension***

Hélio Cabral[1], Leonardo de Souza[1], Roger Mello[2], Liliam Oliveira[1], Taian Vieira[1]

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AIM: Fibers are angled by different amounts along the vastus medialis (VM) muscle; distal fibers are oriented more obliquely to the quadriceps tendon than the proximal fibers [1]. Consequently, the direction of the resultant force vector may be shaped according to the distribution of activity along VM. Based on previous evidence, suggesting the fibers of different motor units may reside within distinct VM regions [2], here we investigate whether knee extension demands a differential modulation of motor units serving different, proximo-distal VM fibers. METHODS: Ten healthy, male subjects (range: 24-32 years; 168-182 cm; 70-85 kg) were recruited. While seated comfortably on a dynamometer chair, with the knee held flexed at 80 deg, participants were asked to isometrically contract their knee extensor muscles. Visual feedback was provided to ensure that participants could successfully modulate their knee extension force according to a trapezoidal profile: from 0% to 20% of their maximal force in 5 s, at 20% for 10 s and then back to 0% in 5 s. Two arrays of eight electrodes were used to sample electromyograms (EMGs), each aligned parallel to VM proximal and distal fibers. EMGs were decomposed into trains of motor unit action potentials [3]. The cross-correlation function was then calculated for the firing pattern of: i) pairs of motor units identified from the same VM region; ii) pairs of motor units decomposed from EMGs detected proximally and distally. Kruskalwallis and Dunn-Sidak post-hoc tests were performed to compare how strongly modulations of firing rate in the two regions were similar during knee extension. RESULTS: Analysis revealed a significant difference in cross-correlation values between VM regions. The firing rate varied significantly more similarly for pairs of motor units identified from the same VM region, both proximal and distal, than for pairs of units in different muscle regions. CONCLUSION: Our results suggest that, at least during low level, isometric knee extension contractions, the firing rate of motor units identified from different VM regions may be modulated independently. It is therefore possible the nervous system tunes the VM force direction by shaping the distribution of activity within the muscle. [1] Smith, Nichols, Harle (2009) Do the Vastus Medialis Obliquus and Vastus Medialis Longus Really Exist? A Systematic Review. Clin Anat. 199: 183-199 [2] Gallina, Vieira (2015) Territory and fiber orientation of vastus medialis motor units: a surface electromyography investigation. Muscle Nerve. 52(6):1057-65 [3] Holobar, Zalula (2004) Correlation-based decomposition of surface electromyograms at low contraction forces. Med Biol Eng Comput. 42: 487-495.

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O.12.5 *Initial estimates of motoneuron after-hyperpolarization through the tonic discharge of motor unit populations*

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BACKGROUND AND AIM: Animal investigations provide a wealth of information regarding the biophysical properties of motoneurons. The translation of these findings to humans is limited, in part, by our inability to perform invasive recordings in humans. For example, recordings of motor unit action potentials (MUAPs) from muscle fibers provide limited information regarding the trajectory of membrane potentials in the soma of the corresponding spinal motoneuron. Motoneuron discharge can be faithfully assessed through identifying the activation of its associated muscle fibers. In turn, these discharge characteristics may afford valid estimates of membrane potential trajectories of spinal motoneurons, in particular the duration of the after-hyperpolarization (AHP). METHODS: The EMG activity underlying the tonic discharge of soleus motor units from the decerebrate cat is collected using a 64-channel electrode array and decomposed into corresponding MUAP spike trains. Interval death rate analyses are used to estimate the duration of the AHP for motor unit spike trains containing >1000 spikes. RESULTS: Our analyses focus on long trains of tonic discharge from 74 unique motor units from across 6 experiments. The validation and yield of these spike trains was improved through tracking the spike triggered average-derived MUAP waveforms across subsequent trials, resulting in an average of 1490 spikes per unit. These tonic motor units discharged at low rates (8.4±1.3 [SD] pps) with low variability (16.9±6.1 %CoV). By visually approximating the noise transition of the death rate function, the average duration of the AHP of soleus motoneurons is estimated as 134±18.3 ms. To assess the stability of the AHP, extremely large spike trains (>2000 spikes) could be separated in half, providing two continuous, nonoverlapping spike trains from the same unit. Using this approach, AHP estimates demonstrated good reliability across 16 motor units with an intraclass correlation coefficient of 0.84. The distribution of 27 motor units from a single soleus motor pool, yielded a range of AHP durations that was similar to the range of all 74 units recorded across animals. A strong negative correlation is observed between the duration of the AHP and the mean discharge rate ($r = -0.88$; $p<0.001$) of a given motoneuron. CONCLUSIONS: Interval death rate analyses from the tonic discharge of soleus motor units in the cat provide reliable estimates of the AHP duration. These AHP duration estimates closely mirror the central tendencies of soleus motoneuron AHP durations from previous investigations, which acquired direct measurements through intracellular microelectrodes. The current data suggests the AHP may serve a prominent role in the regulation of the tonic discharge of soleus motor units. Developing parallel means to assess motoneurons in both animals and humans will aid our ability to understand spinal neuron changes in both health and disease.

O.12.6 *The Temporal Structure of Intermuscular Motor Unit Synchronization: Application of Wavelet Coherence*

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BACKGROUND AND AIM: Intermuscular motor unit synchronization (IMUS) is typically described using a Fourier-based coherence analysis between two EMG signals. Such analyses have demonstrated that IMUS between quadriceps muscles is task-dependent with enhanced synchronization during dynamic tasks. Within a dynamic task, the varying biomechanical conditions suggest an additional time-dependent property of IMUS. However, the lack of time resolution of Fourier-based coherence does not allow to investigate such temporal features. The extension of coherence to the wavelet transform combines good time and frequency resolution and thus allows to investigate the temporal structure of IMUS. The aim of this study was to test the application of a wavelet based coherence analysis to examine the temporal structure of IMUS between Vastus Lateralis (VL) and Medialis (VM) during gait. METHODS: Surface EMG signals from VL and VM were recorded from eight young adults during walking on a treadmill (40 strides) at their preferred speed. EMG signals were resolved into time-frequency space using 13 non-linearly scaled wavelets with center frequencies between 2-191 Hz. The wavelet cross- and power spectra were time-normalized to 100% of stride duration and averaged across strides. The wavelet coherence was then calculated as the squared wavelet cross spectrum normalized by the product of the individual wavelet power spectra. A

reference coherence was defined as the coherence between the VL EMG and the VM EMG shifted by one stride. This reference coherence was subtracted from the wavelet coherence to remove any artificial coherence due to motion artifacts. The resultant wavelet coherence patterns for each subject were displayed for center frequencies between 32-191 Hz and for the time interval of 20% before and after heel strike when the Vastii muscles are most active. RESULTS: The wavelet coherence patterns showed both common and subject specific features. Except for subject #6, VL and VM EMGs were coherent intermittently for all subjects before and after heel strike. Significant coherence was generally present in three frequency bands: 45 Hz, 76 Hz, and 116 Hz. Particularly, subject #1 and #5 demonstrated high coherence in the 116 Hz and 45 Hz band, respectively. CONCLUSIONS: The wavelet coherence successfully resolved the temporal structure of IMUS between VL and VM during walking. Despite both muscles being active, coherence between VL and VM is not constant but rather occurs intermittently at specific time points before, during, and after heel strike. The presence of significant coherence between VL and VM EMGs in the frequency range between 45-76 Hz aligns with previous findings and demonstrates the validity of this approach. We speculate that the coherence in high frequency bands represents synchronization of individual motor units while coherence in low frequency bands indicates synchronized clusters of motor units in both muscles.

S.9. *Implementation of Impairment Based Neuro-Rehabilitation Devices and Technologies following Brain Injury*

The use of haptic robots to study neural mechanisms underlying the expression of sensorimotor impairments in stroke.

Julius Dewald[1], Albert Chen[2], Jun Yao[1]

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BACKGROUND AND AIM: The implementation of electromechanical devices for the quantification, study and treatment of sensorimotor impairments (abnormal muscle synergies, spasticity, reduced reflex modulation, paralysis and proprioceptive deficits) resulting from brain injury is the main topic in this symposium. The specific requirements for the use of robotic devices to quantify these impairments, as well as study and ultimately treat them effectively, will be discussed by the various presenters. A case will be made that electromechanical devices not only allow the clinician to quantitatively control task practice and dosage, but more importantly, allow for the study and subsequent development of more targeted treatments of specific impairments, such as the expression of abnormal movement synergies. The use of robotics to study mechanisms underlying the expression of the flexion synergy will be discussed in this presentation. The flexion synergy consist of abnormal coupling between shoulder abduction and elbow/wrist and finger flexion in individuals with hemiparetic stroke. When increasing shoulder abduction, reaching distance and hand opening will become progressively more limited. METHODS: Eight able-bodied control subjects and 8 moderately to severely impaired individuals with chronic stroke with a single unilateral subcortical lesion participated in this preliminary study. All subjects performed ballistic reaching movements from a home target position. Three shoulder abduction loads were applied during reaching: 1) sliding on a haptic "table surface"; 2) reaching in free space with the limb fully supported by our haptic robot and 3) reaching in free space while lifting a load equal to 25% of the subject's maximum abduction force. A total of 120 trials were performed for each condition. Kinematic and HD-EEG signals (n=160) were recorded during the execution of this controlled motor task. RESULTS: Data will be presented that shows that as shoulder abduction loading is increasing, medicated by our robot, a concurrent increase in ipsilateral sensorimotor cortical activity is observed using high-density EEG. CONCLUSIONS: It is postulated that the proportional increase in ipsilateral cortical activity, as a function of shoulder abduction loading, results in activation of the ispilateral reticulospinal projections that have been shown to activate shoulder abductors and elbow/wrist and finger flexors hence resulting in a coactivation of muscles generating the flexion synergy. The need for a development of robot-medicated treatments that promote an increased use of the contralateral, lesioned, hemisphere, so as to reduce the expression of the flexion synergy, will be briefly discussed.

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Robotic assessment of the "good arm" following stroke

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Background and Aim: Impairment in the ipsilesional or ?good arm? following stroke is often discussed in the literature, but rarely treated in clinical practice. Many studies have investigated impairments of the ipsilesional arm in the chronic phase, but few examinations have been made in the subacute phase. In the literature, most measures of ipsilesional motor function have been made with observer based ordinal scales. These scales are typically not sensitive to more subtle, but important deficits in motor function. Robotic technology offers the ability to perform sensitive and highly reliable assessments of sensorimotor function. In the present study we used robotics in the subacute phase post-stroke to quantify motor function of the contra- and ipsilesional arms post-stroke. The aim of the study was to increase our understanding of the nature and prevalence of motor deficits in the ?good arm? following stroke. Methods: We examined 259 subjects with first time, unilateral stroke using a KINARM exoskeleton robot. Each subject completed a robotic assessment of visually guided reaching in both arms. Subjects also completed a variety of traditional clinical measures (Functional Independence Measure, Chedoke-McMaster Stroke Assessment, Purdue Pegboard) in order to make comparisons to robotic measures. Results: We found that impairments in the ipsilesional and contralesional arms were only moderately correlated for robotic measures of reaching (r values varied from 0.3 to 0.6 depending on parameter). Ipsilesional deficits occurred in 34% of subjects. Interestingly, the magnitude of impairment of the contralesional arm was similar for subjects with and without ipsilesional deficits. Conclusion: In summary, traditional thinking that impairment of the contralesional arm usually predicts ipsilesional impairment seems to be incorrect. Many subjects had quite severely impacted contralesional arm impairments with either no or negligible impairment of the ipsilesional arm. Robotic technology allows better characterization of visuomotor deficits than many traditional measures and may be helpful in personalizing rehabilitation strategies after stroke.

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Robotic Measurement and Intervention for Synergy-Related Reaching Dysfunction Following Stroke

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[1]Northwestern University

The onset and progression of upper extremity flexion synergy, also described as a loss of independent joint control, can be precisely measured beginning with the emergence of volitional movement in early recovery following stroke (see figure below illustrating the kinematic/kinetic measure of reaching workarea as a function of abduction loading). More specifically, the impact of flexion synergy on reaching function can be quantified with the robotic device, ACT3D. With this device, variable amounts of abduction support (also abduction resistance) are provided while the individual attempts to reach maximally in a horizontal plane at shoulder height creating a hand path envelope representing the total reaching range of motion. The resultant 2-dimentional area of the hand path envelope is calculated representing the "workarea" as a function of abduction loading. In this symposia talk, data will first be presented illustrating the ubiquitous expression of flexion synergy upon emergence of movement during early recovery even in individuals who transition to complete recovery of reaching function. Additionally, data will be presented illustrating the persistence of flexion synergy-related reaching dysfunction in individuals who transition to chronic severe impairment. An intervention strategy for targeting flexion synergy will then be discussed illustrating the capacity for robotics to serve as an effective exercise tool to ameliorate flexion synergy-related reaching dysfunction in severe chronic stroke. Initial studies implementing this approach indicate that progressing shoulder abduction loading as individuals improve in reaching range of motion is a key therapeutic attribute for restoring reaching function. Data from both early and chronic recovery suggests future investigation of the safety and effectiveness of targeting flexion synergy-related reaching dysfunction in early recovery in an effort to optimize the recovery trajectory.

Using Robotic Systems to Assess Proprioceptive Deficits in Individuals with Hemiparetic Stroke

Netta Gurari[1]

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Background and Aims: According to clinical assessments, nearly 70% of stroke survivors have compromised proprioception. Even so, our understanding about the reason for observed deficits based on currently available clinical proprioceptive assessments is limited since measurements: (1) lack sensitivity to identify the degree of a deficit (e.g., ratings are unimpaired, mildly impaired, severely impaired), (2) are subjective (e.g., a rater determines task performance based on visual inspection), (3) may not be reliable (e.g., ratings may differ depending on the rater and testing session), and (4) may be confounded by additional impairments. To address limitations of currently available clinical assessments, a number of research groups are employing robotic systems to standardize and automate the assessment of proprioceptive capabilities in individuals with stroke. Robotic systems allow for a number of advantages including the following. First, a single robotic device can create various types of virtual touch environments. For example, a user may feel at one moment as though he or she is moving the hand in free space, and a moment later that his or her hand is being moved by the robotic device. Second, sensors affixed to the robotic device can monitor the user's interaction, and the sensor data can be stored for off-line processing. In this work, I aim to demonstrate, using a robotic device, that proprioception within the paretic arm and non-paretic arm of individuals with chronic hemiparetic stroke may not be impaired even if these individuals have deficits matching positions across both arms. Methods: I investigated whether individuals with chronic hemiparesis who have deficits matching positions across both arms also have deficits matching positions within a single arm. Participants with chronic hemiparetic stroke having clinically determined mild elbow proprioceptive deficits (i.e., participants with stroke) and age-matched participants without neurological impairments (i.e., controls) partook in the experiments. A custom robotic system was used to quantify each participant's position matching capabilities during single arm and between arm position matching tasks. Participants wore a blindfold and noise-canceling headphones to ensure that they discriminated positions based on proprioceptive cues and not visual and auditory cues. Results: Results from the between arm position matching tasks demonstrate that, aligned with the clinical assessment findings, the participants with stroke performed significantly worse than the controls. However, results also reveal that the participants with stroke performed just as well as the controls during the single arm position matching tasks. Conclusions: Based on these findings, I propose that proprioception may be unimpaired both in the paretic arm and non-paretic arm of individuals with hemiparetic stroke who exhibit large matching errors during bimanual position matching tasks.

Training modalities in robot-mediated upper limb rehabilitation in stroke

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Upper-limb rehabilitation robotics can be beneficial tools for robot-assisted therapy. These technologies provide motivational and interactive therapy for the patient and can perform quantitative measurements of post-stroke impairments and degree of recovery for therapists and clinicians. A major question is in which way technology can provide the largest benefit, especially regarding application in clinical practice. The types of devices that are available for upper-limb rehabilitation can be classified as weight-support devices, robotic endpoint manipulators, and exoskeletons. Each of these have specific advantages and disadvantages. We have classified eight training modalities that are commonly used by these devices, yet currently not enough evidence exists to determine their exact impact on the rehabilitation outcome. In an attempt to better determine what are the most effective components of upper-limb rehabilitation, we have compared the outcomes of most clinical studies that use robotic rehabilitation to studies that focus on constrained induced movement therapy (CIMT), electrical stimulation therapy (EST), or mirror therapy (MT). We compared the results of the Fugl-Meyer Assessment (FMA) of Motor Recovery after Stroke, but found little differences. When comparing involvement of proximal (shoulder, elbow) or distal components (wrist, hand) in the therapy, again little differences can be found. Combining both proximal and distal therapy does seem to hint (without statistical evidence) at a higher effect on the FMA outcomes, which would be logical as the FMA contains specific proximal and distal components. Interestingly, in chronic studies there does seem to be a clear regression to a mean improvement of about 4.0 on the FMA. That is, the outcome of a randomized clinical trial (RCT) study will regress to 4.0 if more subjects are included. Results with fewer subjects are more likely to diverge, with the variance of study means inversely correlated with the number of subjects. The few studies that report above-expected results are now of most interest, with one study using EST showing most promise. The most disturbing results perhaps is that correlating study outcomes to the year of publication shows little effects of all research efforts in the last two decades. For the current therapies, active physical and mental involvement of the individual after stroke and the number of repetitions appear to be the most important components to achieve improvements on the FMA in RCTs, but the exact type of therapy, devices or training modalities seems to have little to no influence. However, preliminary evidence exists that more individualized and impairment-directed therapies could have a stronger influence, as the other presenters in this workshop might demonstrate.

4D EEG: Assessing the role of the sensorimotor cortex in reflex modulation during motor control.

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The motor cortex is involved in initiating the volitional motions of the muscular system. Through the direct connection between primary motor neurons and á-motor neurons, the muscles are being activated. In addition, it is hypothesized that the motor cortex is involved in the modulation of the reflex gains at the spinal cord level, thereby adapting the impedance of the limbs. The impedance of the limbs is the result of the segment inertia, the muscle stiffness and viscosity and the proprioceptive reflexes, i.e. the position and velocity feedback through the muscle spindles, and the force feedback through the Golgi tendon organ. It has been frequently shown that the impedance is being modulated, e.g. by muscle co-contraction increasing the visco-elasticity, and by the reflex modulation. However, since the neuromuscular control system is a closed-loop system, one has to impose an external signal to identify the properties of the elements inside. We are using robot manipulators with multisine force perturbations with specific frequencies to perturb the neuromuscular system, and measure the position, force and muscular EMG. Neuromuscular parameters like muscle visco-elasticity and position, velocity and force feedback can be calculated from the Frequency Response Function. Variations of parameters over time can be assessed using a Linear Time Varying (LPV) system identification paradigm in the time domain. In the experiment the subjects were requested to move their hand back- and forward. During the movement continuous force perturbations were applied. In the LPV algorithm, position was used as scheduling function, and a time-varying state space model was estimated on the data set. After fitting a neuromuscular model to the state space model, with mono-articular shoulder and elbow muscles and also bi-articular muscles, it showed that the intrinsic muscle viscosity and reflex gains varied regularly with the change of position. The VAF in lateral-medial direction was 92% and in forward/backward direction 73%, affected by the volitional motion. Feedforward (volitional) muscle control for a complex system as the shoulder and elbow might be relatively easy compared to the reflex gain control in order to provide the desired impedance. Such a highly multivariable and coupled system is unequalled in robotic control. It is likely that larger parts of the cortex, and presumably the motor cortex, is occupied with this task. The total reflex gain is a combination of tonic drive to the á-motor neuron, the presynaptic inhibition and the ã-motor neuron activating the intrafusal muscle fibers. It is hypothesized that the motor cortex is involved in the presynaptic inhibition and ã-motor neuron activation. Goal of the 4D EEG project is to track the propagation of neural signals through the brain, with a spatial accuracy of 2 mm (using EEG source localization) and a temporal accuracy of msec. In the 4D EEG project the EEG responses to the multisine force perturbations are being recorded. About 85% of the EEG signal power is due to non-linear contributions, showing up in higher harmonics of the EEG signal. Using MultiSpectral Phase Coherence (MSPC) the time-delay can be accurately assessed. The challenge is to fit a non-linear dynamic model to the data, which would be for the first time result in a quantitative model of the cortical activity. The current study showed that the gain settings are continuously modulated, presumably in a feedforward manner simultaneously with the muscle activation. The role of the motor cortex in the modulation can be recorded using EEG source localization.

S.10. ***Neural mechanisms underlying falls and impaired balance: an introspective from animal to patient***

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Are Hypermetric Stretch Reflexes Significant Contributors to Falls in Stroke Survivors?

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BACKGROUND AND AIM Half of the 6.5 million stroke survivors living with disability in the US fall each year. Despite this statistic, remarkably little information is known about the sensory mechanisms that contribute to falls in this population. The objective of this study was to evaluate the stretch reflex response, known to be abnormal following stroke, during laboratory induced "falls." The importance of the stretch reflex in the ability to resist perturbation throughout the body is well documented. Further, we have previously shown that muscle spindle afferents, which drive stretch reflex responses, can provide information about the direction, amplitude, and velocity of a perturbation during a whole-body balance disturbances. Still, these previous studies have predominately been evaluated during postural challenges where a step was not needed and a fall did not occur. Thus, the role of stretch reflex pathways during postural challenges that induce a fall is unknown, particularly in stroke survivors. Given the heightened stretch reflex response that often accompanies stroke in the form of spasticity, we hypothesized that stroke survivors would have larger stretch responses when they fell. METHODS We evaluated 16 unilateral stroke survivors and exposed them to backward perturbations requiring a forward step to maintain balance. Subjects were fitted with a harness such that injury could not occur if a loss of balance occurred. A "fall" was recorded if the subject became unambiguously supported by the harness. We evaluated kinematics (e.g. trunk flexion) as well as muscle activity in the paretic and non-paretic rectus femoris, semitendinosus, and gastrocnemius muscles. The time window of 50-100ms was considered the stretch reflex response. RESULTS Sixteen trials resulted in a fall and 9 subjects were classified as Fallers. We found larger stretch reflex (50-100ms) responses in the paretic rectus femoris muscle during fall trials and in subjects classified as Fallers. This activity was sensitive to perturbation size indicating it is the likely result of stretch sensitive pathways. Importantly, there were no significant differences seen in trunk flexion at the time of the stretch. This indicates that the heightened stretch response is not related to the subject experiencing a larger perturbation during the fall but rather due to an intrinsically heightened response. CONCLUSIONS Given previous reports showing that large hip flexion during a balance disturbance increases the likelihood of a fall, our results suggest that abnormal stretch reflex responses may contribute to larger hip flexion putting stroke survivors at risk of falling. Still further study is needed to fully determine the functional consequences of this hypermetric stretch reflex response. Finally, future work should evaluate if clinical measures of spasticity may be an appropriate predictor of falls.

Strategies to maintain static and dynamic lateral stability during locomotion in the cat

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BACKGROUND AND AIM: During walking, cats as humans are less statically stable in the frontal plane than in the sagittal one due to geometry of the base of support (Winter 1995; Misiaszek 2006). Given similarities in postural responses of walking cats and humans to lateral perturbations (Misiaszek 2006; Hof et al. 2010), cats appear to be a convenient animal model to study neural mechanisms and biomechanical strategies of lateral balance control during locomotion. METHODS: In a series of studies, we investigated the static and dynamic stability of cats when lateral balance was challenged by (1) constraining step width to 5 cm during overground walking, (2) changing the speed difference between the two treadmill belts during split-belt treadmill walking, (3) removing cutaneous input from the fore- and hindpaws of one side of the body using anesthetic injections, and (4) osseointegrated transtibial passive prosthesis during overground walking. Static stability was determined as the shortest distance between the vertical projection of the center of mass of the body (CoM) and the boundary of the support area in the lateral direction, whereas the margin of dynamic stability was defined as the difference between the center of pressure (CoP) and the extrapolated center of mass (xCoP, Hof et al. 2007) or as the difference between CoP and the boundary of the support area (Farrell et al. 2014, 2015). CoM position was computed using 3D recordings of 28 markers on major

body segments and a full-body cat model with known inertial body segment parameters (Hoy, Zernicke 1985). CoP was derived from paw position and ground reaction forces measured by an instrumented split-belt treadmill. RESULTS: Despite very different mechanical or sensory challenges to lateral balance, the adopted strategies to maintain lateral balance were similar. Cats increased step width except when it was constrained, increased the area of support and relative time spent in 3-legged support, decreased the duration of the double support phase by fore- and hindlimbs on the affected body side (prosthetic, anesthetized or moving faster on the split-belt treadmill), and shifted body weight and CoM towards the contralateral side except during anesthesia of paws when the body shifted in the opposite direction. As a result of these changes in locomotor mechanics, margins of static and dynamic stability in the direction of the affected body side increased. For example, dynamic stability margins during double support by fore- and hindlimb of the affected side (prosthetic gait or walking with anesthetized paws) were typically greater than 2 cm and exceeded those on the contralateral side by 2 times. Increases in margins of dynamic stability have also been found during prosthetic walking in human amputees (Hof et al. 2007). CONCLUSIONS: The obtained results provide important new insight into possible strategies for improving lateral stability during walking in challenging conditions.

New rehabilitation tools and technologies to improve balance and mobility

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The control of posture and upright balance requires complex multisensory integration and sensorimotor coordination. Information from multiple sensory channels is processed, and appropriate muscles are activated for appropriate action with, and adaptation to environmental demands. Sensory and motor systems compromised with aging or neurological diseases such as stroke likely impede this process. Extensive human and animal studies have shown, however, that improvements in sensorimotor functions can result from experience-dependent neuroplasticity achieved through salient, repetitive, intensive and motivating practice. New technologies, based on virtual reality (VR) and robotics, have the capacity of simulating environments, providing a new and safe way to not only increase practice time but also to create the varied environments and controlled constraints needed to maximize learning (Darekar et al, 2015). An advanced balance and locomotor system that combines VR with a self-paced treadmill mounted on a motion platform has been developed to allow patients to be exposed to more complex physical environments (both indoors and outdoors) including environmental hazards without physical danger (Fung et al, 2006). VR systems can be combined with the manipulation of physical environments and sensory feedback to create a mixed reality system for multisensory integration and sensorimotor enhancement. Sensory manipulation with augmented cues from the visual, auditory and proprioceptive systems can be used to enhance motor functions for the control of balance. Haptic touch has emerged as a novel and efficient technique to improve postural control and dynamic stability. Improvement of balance and mobility functions with a mixed reality system incorporating VR, surface perturbations and haptic manipulation is evidenced by kinematic and kinetic changes in postural adaptations and reactions. Furthermore, the enhancement of sensorimotor integration is revealed by cortical activation changes measured with near-infrared spectroscopy (Sangani et al, 2015). This symposium presentation will focus on evidence-based tools and technologies that can be used to evaluate and enhance posture and balance control in post-stroke and older adults. References: Darekar A, McFadyen B, Lamontagne A, Fung J (2015) Efficacy of virtual reality based intervention on balance and mobility disorders post-stroke: a scoping review. J NeuroEng Rehabil 12:46. Fung J, Richards CL, Malouin F, McFadyen BJ, Lamontagne A (2006) A treadmill and motion coupled virtual reality system for gait training post-stroke. Cyberpsychology and Behavior 9(2):157-162. Sangani S, Lamontagne A, Fung J (2015) Cortical mechanisms underlying sensorimotor enhancement promoted by walking with haptic inputs in a virtual environment. Progress in Brain Research 218: 313-30.

Balance reactions following perturbations to touch are more pronounced when standing on an unstable surface

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BACKGROUND AND AIM: Lightly touching a stable reference reduces sway during standing. Recently, we demonstrated that rapid displacements of a touch reference

leads to fast reactions in leg muscles during standing with eyes closed, suggestive of a balance reaction. However, these presumptive balance reactions were only seen in half of the participants, and were only observed following the first exposure to the perturbation. We suggest that fingertip cutaneous cues can evoke balance corrections, but that their expression is context dependent. In the present study, the challenge of the task was increased by asking the participants to stand on foam with their eyes closed. Standing on foam creates mechanical instability, but also is argued to impair feedback from the feet and ankles. We hypothesized that participants would increase their reliance on the touch cues to stabilize balance and that this would be reflected by increased expression of balance reactions with displacement of the touch surface. METHODS: 20 participants were asked to stand on foam placed atop a force plate. Electromyographic activity was recorded from the right tibialis anterior (TA), soleus (SOL), anterior deltoid, posterior deltoid and sternocleidomastoid, along with electrogoniometer records from the right elbow, hip and ankle. Participants stood naturally in 4 conditions: a) eyes open, b) eyes open while touching, c) eyes closed, and d) eyes closed while touching (ECT). Conditions a-c were used as a deception. During ECT participants stood quietly while lightly touching (< 1 N) a touch plate for 1 min before touch plate displacements (12.5 mm, 124 mm/s) were unexpectedly introduced. Displacements were separated by a period of 6-15 s. Participants received a block of 10 displacements in a single direction (forward or backward). Half received forward perturbations. RESULTS: All participants responded to the touch plate displacement with a balance reaction at the ankle in at least two trials. 6/10 participants responded with TA activation following the first exposure to forward touch displacement and importantly, with a median response rate of 8.5 per participant across all 10 trials. 8/10 participants responded with SOL activation following the first exposure to backward touch displacement, with an overall median response rate of 6 per participant across all 10 trials. 14/20 participants responded in trials 9 and/or 10. CONCLUSIONS: These results confirm that cutaneous inputs from the fingertip can induce a balance corrective response, even in the absence of an overt balance disturbance. Importantly, the contribution of light touch to balance control is augmented in conditions when other sensory sources are impaired or unreliable, even though participants became aware that the touch cue itself was unreliable. This suggests that cutaneous input from the hands is an important sensory cue in balance control when the hands are engaged in balance tasks.

Basic insights in tripping responses can assist in designing appropriate fall prevention programs.

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To understand the neural mechanisms of falls it is essential to consider the circumstances leading to a fall. Many falls occur during walking and are due to unsuccessful trip recovery (Robinovitch et al., 2013; van Dieën & Pijnappels, 2008). Hence the need to study tripping responses generated under these circumstances. From animal studies it appears that stumbling reactions are organized at a low level in the nervous system. The studies on humans give a similar picture. Responses after stumbling occur with a latency which is below those seen in voluntary motor actions, suggesting they are involuntary reactions. These responses are smaller and slightly later in elderly as compared to young adults. However, these responses do not determine the strategy used to overcome the obstacle (short or long step strategy). In addition it was shown that the crossing behavior and movements could be adjusted while ongoing (hence they are not ballistic movements; see Potocanac et al., 2016). Finally, following the tripping responses there is a substantial period before touching the ground in case of an unsuccessful recovery attempt. The latter prompted us to experiment with training methods to teach elderly to fall safely, based on martial arts techniques. It was demonstrated that these techniques reduce the fall impact. Furthermore, a fall prevention training program was able to reduce falls and to improve obstacle avoidance skills. It is concluded that basic insights in tripping responses can assist in designing appropriate fall prevention programs.
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Altered sensorimotor transformations for balance in Parkinson's disease

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BACKGROUND AND AIM: Automatic postural responses to balance perturbations are often abnormal in Parkinson's disease (PD), which may increase fall risk. However, pathological changes underlying abnormal postural responses are poorly understood, limiting our ability to develop improved therapies. We have developed a mechanistic model of the sensorimotor feedback transformation used to activate muscles during postural responses: the Sensorimotor Response Model (SRM). Previous work in animals and in young healthy individuals demonstrated that postural responses are created through multisensory estimates of the motion of the center of mass (CoM) that activate muscles in an optimal tradeoff between postural error and neural effort to stabilize the body. Here, we used the SRM to test whether this sensorimotor transformation is altered in PD. METHODS: We compared postural responses to backward support-surface perturbations in two female patients: one with moderate PD and falls history (age, 75 y; Hoehn & Yahr stage 3), and one with mild PD and no falls history (54 y; Hoehn & Yahr 1.5), with those from healthy older (70 y, no falls history) and healthy young (19 y) female participants. We quantified average electromyographic (EMG) responses in agonist medial gastrocnemius (MGAS) and antagonist tibialis anterior (TA) with SRM parameters, including feedback gains on CoM jerk (kj), acceleration (ka), velocity (kv), and displacement (kd). RESULTS: Altered SRM parameters accounted for abnormal agonist-antagonist co-contraction in PD. While healthy participants maintained balance primarily via activation of agonist MGAS, PD patients maintained balance primarily via agonist-antagonist co-contraction, with increased SRM parameter magnitudes in antagonist TA ($P<0.001$) but not in agonist MGAS ($P<0.25$). Altered SRM parameters also accounted for shortened EMG initial bursts in PD, which were most pronounced in the individual with moderate PD. PD EMG responses exhibited elevated SRM paramter kj ($P<0.05$, ANOVA) and a trend towards elevated ka ($P<0.10$), suggesting that contributions of higher-order derivatives of CoM motion to muscle responses

were elevated in these individuals compared to controls. Overall, delayed sensorimotor feedback of CoM motion was sufficient to reproduce recorded muscle activity with high precision in all participants (variance accounted for = 0.87±0.09). CONCLUSIONS: These results provide initial evidence that sensorimotor transformations during balance control are altered in PD, resulting in EMG responses with abnormal magnitude and timing. Larger prospective studies are required to establish temporal relationships between altered postural responses, disease onset, and the appearance of falls. Refinements of the SRM may provide insight into how PD affects balance and enable clinicians or therapists to better direct individuals to interventions to mitigate fall risk.

S.11. *EMG Signal Analysis in Clinical Applications*

The use of EMG in neuromuscular diagnosis: an overview

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INTRODUCTION: EMG is the measurement of electric muscle activity: - during voluntary activation (interference pattern) - after electric pulses over a peripheral nerve evoking a compound muscle action potential (CMAP) - similarly, as motor evoked potential (MEP) after transcranial magnetic brain stimulation (TMS). In clinical practice, both needle- and surface-EMG are used for different applications. NEEDLE EMG: Thanks especially to the pioneering work of Buchthal [1] and Stålberg [2], needle-EMG is well standardized in clinical diagnostics observing voluntary activation. Crucial in needle EMG is the quantification of motor unit action potentials (MUAPs) or single muscle fiber potentials (SFAPs), estimating both the activity and the properties of single motor units, the basic functional building blocks of a muscle and even of single muscle fibers. CONVENTIONAL SURFACE EMG: Single channel surface EMG is the standard for compound muscle activity after nerve or cortex stimulation. It supports the diagnosis of peripheral nerve conduction and central nerve conduction both in terms of a possible loss of axons and decreased conduction velocities. It is also connected to standardized clinical protocols [3]. HIGH-DENSITY

SURFACE EMG: New possibilities came up with multi-channel surface EMG, especially versions with small inter-electrode distances up to 10 mm, often denoted as high-density surface EMG (HD-sEMG). It goes back to the work of Gydikov and colleagues [4]. With one-dimensional array electrodes, motor unit action potentials could be followed along the muscle fibers. Later, two-dimensional grids were introduced, first by Masuda and colleagues [5]. It allowed the description of an EMG signal as a spatio-temporal phenomenon instead of a single point observation, making sense from both anatomical and physiological perspective. HD-sEMG methods were developed to also characterize single motor units, to measure action potential propagation along the muscle fibers and to focus observations by spatial filtering. A systematic review in 2006 evaluated the clinical applications of HD-sEMG [6]. At that time and still, most studies are in a stage of bringing mainly important pathophysiological insights. It concerns muscle fatigue, motor neuron diseases, neuropathies, myopathies, spontaneous muscle activity like in ALS and MU firing characteristics. An overview of challenges towards routine clinical applications of advanced surface EMG techniques will be given. REFERENCES: [1] Buchthal F, Neurol Clin. 1985; 3:573-598. [2] Stålberg E, Muscle Nerve. 1991;14:293-303. [3] Johnsen B, Fuglsang-Frederiksen A, Neurophysiol Clin. 2000;30:339-351. [4] Gydikov A, Kosarov D, Electromyogr Clin Neurophysiol. 1972;12:283-305. [5] Masuda T, Miyano H, Sadoyama T, Electroencephalogr Clin Neurophysiol. 1983;55:594-600. [6] Drost G, Stegeman DF, van Engelen BG, Zwarts MJ, JEK. 2006;16:586-602.

A novel method for analysis of pathological tremor in electroencephalograms

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BACKGROUND AND AIM: The role of cerebral cortex in the generation of essential (ET) and Parkinsonian (PD) tremor is not yet fully understood. In the past, it has been investigated non-invasively using coherence analysis between cortical activity, recorded with EEG or MEG, and muscle activity as assessed from EMG. While robust, coherence only indirectly measures corticomuscular coupling, does not support tracking of tremor over a short time scale and requires cleaning of EEG artefacts. We propose a method that circumvents these limitations. METHODS: 5 ET (age 67±6 years, Fahn-Tolosa-Marin scale score of 39±10) and 5 PD patients (age 71±11 years, UPDRSIII scale score of 9±4) participated in the study that was approved by local ethics committee. Patients performed two repetitions of a 30 s long postural task. Surface EMG was recorded from the right wrist flexors and extensors by two arrays of 5 by 12 electrodes (LISiN-OT Bioelettronica, Italy). The signals were band-pass filtered (10-750 Hz) and sampled at 2048 Hz by 12-bit A/D converter (OT Bioelettronica, Italy). EEG was recorded with 32 passive Au or active Ag/AgCl electrodes, placed on the extended 10/20 system cap (g.Tec, Austria), amplified, band-pass (0.5-60 Hz) and notch filtered (50 Hz) and sampled at 256 Hz with 24 bit resolution (g.Tech, Austria). A common clock signal was used to synchronize the EEG and EMG recordings. EEG signals were manually inspected to ensure the absence of head tremor or tremor-related movement artefacts. We identified 6±3 (ET) and 9±5 (PD) motor units (MU) from each muscle by CKC method [1]. Discharge patterns of all MUs were assessed with >90 % accuracy, as verified by Pulse-to-Noise Ratio [1]. Their cumulative spike train (CST) was used to construct a Linear Minimum Mean Square Error (LMMSE) estimator of the tremor component in EEG. Finally, the coherence between the CST and the extracted EEG tremor component was compared to the coherence between the CST and Laplacian-filtered EEG at C1 position. RESULTS: The CST-C1 coherence was 0.02±0.03 (range 0.001 - 0.12) in ET and 0.01±0.02 (0.001 - 0.09) in PD patients and increased significantly (Wilcoxon signed rank test, $p<0.0001$) to 0.13±0.09 (0.005 - 0.42) in ET and to 0.1±0.09 (0.014 - 0.45) in PD patients when computed between the CST and the LMMSE tremor estimate. The relative power of the first tremor harmonic in extracted tremor components with significant corticomuscular coherence was stronger in PD than ET patients (Kruskal-Wallis test, $p < 0.05$). CONCLUSIONS: The presented technique extracts tremor-related component from EEG and supports detailed tremor analysis and discrimination of PD and ET patients. This study was supported by Commission of the European Union, within Framework 7 (projects NeuroTREMOR and FP7-PEOPLE-2013-IOF-627384) and by Slovenian Research Agency (projects L5-5550 and J2-7357). [1] Holobar A. et al. 2014, J Neural Eng. 11(1):016008.

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High Density Surface EMG Examination of Motor Unit Firing Behavior in Amyotrophic Lateral Sclerosis

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BACKGROUND AND AIM: Electromyogram (EMG) examination has been used for diagnosing and tracking amyotrophic lateral sclerosis (ALS). Compared with routine examinations, such as detection of fibrillation and fasciculation potentials, quantitative motor unit action potential analysis and motor unit number estimation, motor unit firing behavior alterations in ALS have not been widely studied. The objective of this study was to examine motor unit firing behavior of ALS patients using high density surface EMG decomposition. METHODS: Surface EMG signals were recorded from the first dorsal interosseous (FDI) muscle of 10 ALS subjects (age 53.1±12.5 years) and 10 matched neurologically intact subjects (age 51.2±15.3 years) using a flexible 64-channel surface electrode array (8 by 8 electrodes, inter-electrode distance of 4 mm). Each subject was asked to perform a series of 10 s long isometric contraction at different force levels ranging from 10% to 100% of maximum voluntary contraction (MVC) at 10% increment. Sufficient rest time between trials was provided to avoid mental and muscle fatigue. The surface EMG signals were sampled at 2 kHz per channel with a band-pass filter of 5-500 Hz (TMS International BV, Netherlands), and decomposed offline using the Convolution Kernel Compensation (CKC) technique [1]. The motor unit firing behavior was examined for both ALS and matched control subjects. RESULTS: The MVC force of the tested FDI muscles ranged from 1.5 to 32 N for the ALS subjects, and from 19 to 46 N for the matched control subjects. A total number of 675 motor units from the ALS subjects and 1038 motor units from the matched control subjects were extracted. The number of extracted motor units from a single trial, regardless of force level, was 7±4 for the ALS group and 12±5 for the control group. A linear regression model (y=Ax%2BB) was fitted between the mean motor unit firing rate and the contraction force for each subject. For the ALS subjects with mild to moderate weakness, ?A? and ?B? variables were in the same range as the matched control subjects. However, the variables were quite scattered for the 4 ALS subjects with severe weakness (MVC < 5 N). The ALS subjects with very weak muscles tended to have higher motor units firing rates than the

matched control subjects at the same absolute forces. CONCLUSIONS: Our results showed that ALS patients had a similar pattern of motor unit behavior to the matched control subjects, except for those with severe weakness. [1] Holobar A, Zazula D. Multichannel blind source separation using convolution kernel compensation. IEEE Trans. Signal Process 55(9):4487-4496, 2007.

A novel device for assessing pelvic floor muscle function in women

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BACKGROUND AND AIM: Current tools only assess single aspects of pelvic floor muscle (PFM) function, and most are limited to static testing. This study tested the reliability of a novel device for assessing the PFMs during functional activities. METHODS: A self-retaining vaginal device was developed. Two Freescale Semiconductor MPX2300DT pressure transducers were mounted on the device: 1. level with the PFMs (PFP) and 2. superiorly for intra-abdominal pressure (IAP). Two pairs of electrodes were mounted adjacent to the PFMs (PFM_L and PFM_R). The electrodes were interfaced with miniTrignoTM electrodes and the pressure sensors were interfaced with TrignoTM load cell adaptors. Eight pelvic floor physiotherapists, mean age 42 years, were recruited. They performed three repetitions each of PFM maximum voluntary contractions (MVCs) and maximum effort coughs, in supine and standing, on two occasions one week apart. EMG and pressure data were recorded simultaneously at 2000 Hz using a Delsys TrignoTM wireless EMG system. EMG data were rectified and smoothed using the root mean square: 200 ms sliding window, 199 ms overlap. Peak values were extracted. First the independence of the channels was determined. Cross-correlation functions were performed to determine the time lag between the pressure channels. Repeated measures analyses of variance (ANOVAs) were computed to compare the pressure channels and the PFM sides. The mean absolute difference between the sides was calculated and normalized to the higher side (nMAD). Second the between trial reliability was determined. Repeated measures ANOVAs were computed for each channel and task. The coefficient of variation (CV) was computed for each channel, by task and day. Third the test-retest reliability was determined. Spearman?s Rho was calculated between days for each channel and task. Repeated measures ANOVAs were computed for each channel and task. The between days nMAD was also calculated. RESULTS: There were no time lags between the pressure signals ($p>0.05$). The amplitudes were different between the pressure channels for all tasks ($p\leq0.01$) except the supine cough ($p=0.66$). During the MVCs PFP was higher than IAP, during the standing cough IAP was higher. The PFM_R was higher than the PFM_L ($p\leq0.003$). See Table for the nMADs. There were no between trial differences in the peak amplitudes ($p>0.2$). See Table for the CVs and the results for the between day Spearman?s correlations and nMADs. The test-retest ANOVAs displayed significant between day differences in the pressure data ($p<0.02$), but not in the EMG. CONCLUSIONS: The signals recorded by the two pressure sensors were clearly independent, as were the two sides of the PFMs. Between trials, the pressure and EMG amplitudes were not different. Between days the EMG signals were not different, the pressure recordings did change, in a way that suggests learning or functional adaptation. The signals seemed to be less variable in standing than in supine.

Alterations in motor unit firing rate and action potential properties during isometric fatigue in stroke survivors

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BACKGROUND AND AIM: The limited number of studies that have investigated fatigue in chronic stroke survivors during voluntary contractions to the endurance limit have reported relatively higher central fatigue and lower peripheral fatigue on the affected side when compared to the less-affected side and healthy controls (Riley and Bilodeau, 2002; Knorr et al., 2011). Although these changes have been investigated using global indices of motor unit (MU) activation, alterations at the level of the single motor unit have not yet been examined. METHODS: Surface EMG activity was recorded during isometric abduction of the first dorsal interosseous muscle in twelve chronic stroke survivors, before, during and directly after a sustained fatiguing contraction at 30% maximum voluntary contraction (MVC) held until the endurance limit. A series of 10 second duration contractions were performed pre- and post-fatigue, four at 20% MVC and three at 40% MVC. Individual

motor unit spike trains were extracted from the surface EMG signal using the decomposition algorithm outlined in Nawab et al., (2010). The MU action potential waveform was characterised by using the identified MU firing times to spike trigger average the surface EMG signal. Motor units were accepted for further analysis based on the reliability tests outlined in Hu et al., (2013). RESULTS: Motor units on the affected side displayed a greater decline in firing rate during the sustained, fatiguing isometric contraction than on the less-affected side in chronic stroke survivors. Motor unit mean firing rates on both sides exhibited a tendency to be lower directly post-fatigue when compared with pre-fatigue. This was accompanied by evidence of a derecruitment of motor units as fatigue progressed on both the affected and less-affected sides. A significant increase in action potential duration was observed on both sides. However, the magnitude of the change was lower on the affected side. CONCLUSIONS: These results collectively indicate that a higher level of central fatigue is present on the affected side during isometric, fatiguing contractions in stroke survivors. In addition, this study demonstrates that manifestations of peripheral fatigue at the motor unit level, i.e. changes in MU action potential duration, are greater on the less-affected side following voluntary fatiguing protocols. [1] Riley, N. A., & Bilodeau, M. (2002). Changes in upper limb joint torque patterns and EMG signals with fatigue following a stroke. Disability & Rehabilitation, 24(18), 961-969. [2] Knorr, S., Ivanova, T. D., Doherty, T. J., Campbell, J. A., & Garland, S. J. (2011). The origins of neuromuscular fatigue post-stroke. Experimental brain research, 214(2), 303-315. [3] Nawab, S. H., Chang, S. S., & De Luca, C. J. (2010). High-yield decomposition of surface EMG signals. Clinical Neurophysiology, 121(10), 1602-1615. [4] Hu, X., Rymer, W. Z., & Suresh, N. L. (2013). Motor unit pool organization examined via spike-trigge

Contribution of deep and superficial motor units to the surface EMG of the masseter muscle.

Johannes van Dijk[1], Ulrike Eiglsperger[1], Johanna Radeke[1], Hans Schindler[2], Bernd Lapatki[1]

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INTRODUCTION: The masseter muscle is, relatively, the strongest muscle in our body. It is also one of the most complex organized muscles. Localized motor unit territories and task specific motor unit activity enables the masseter to control different muscle portions independently. In this study we aimed at determining the amplitude profiles of masseter motor units in the depth of the muscle and at the skin surface. AIM: Determine the contribution of superficial and deeply located motor units of the masseter to activity measured using surface EMG (sEMG). METHODS: In a cohort of 10 healthy subjects we obtained high-density sEMG (256 channels, inter-electrode distance of 3 mm) of the right masseter during low levels of contractions. Simultaneously, motor unit activity from intramuscular fine wire electrodes is obtained and a monopolar needle is retracted via a stepper motor to obtain the motor unit territory in the depth of the muscle (scanning EMG). Via decomposition of the intramuscular EMG (iEMG) and spike triggered averaging the motor unit potential at the surface is determined. Next, sEMG signals are decomposed into the contribution of individual motor units. The contribution of the deep and superficial motor units to the sEMG is determined. RESULTS: Scanning EMG resulted in a total of 161 MU territories. Small and large MUs were found throughout the muscle depth. MU electrical size from the surface was strongly related to the electrical size determined by macro EMG after correction for depth of the MU. Unfortunately, no units that were decomposed from the surface EMG were detected by the scanning needle. Hence, no direct relation between the surface decomposed signals and MU depth could be obtained. Preliminary results show that a large part of the deeper units are within the noise level of the sEMG and hence can not be obtained for analysis without intramuscular electrodes. CONCLUSIONS: Large and small MUs can be found throughout the depth of the muscle. Our preliminary results show that masseter contains many small MUs that are only in part detectable by the surface electrodes. Hence, as may be expected, superficial and large MUs may be detectable at the surface and their firing patterns can be obtained using sophisticated decomposition techniques. This may bring insight in the possible role of neural alteration due to pain in this muscle. Additional experiments might give more insight in the limitation of the sEMG to see small and deeper MUs.

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S.12. ***Spastic muscle and its treatment using botulinum toxin: new viewpoints with major implications***

Experimental and Modeling Assessments Specific to Treatment Aims Indicate New Viewpoints and an Understanding of Mechanisms of Effects of Botulinum Toxin Type A

Can Yucesoy[1], Filiz Ates[2]

[1]Bogazici University, [2]Waseda University

BACKGROUND AND AIM: Botulinum toxin type A (BTX-A) is widely used in treating spasticity. Partial muscle paralysis helps blocking the hyper-excitable stretch reflexes and reduces active force production. BTX-A is considered to improve function by acting against an agonist-antagonist force imbalance, increasing joint range of motion and decreasing passive resistance. However, a comprehensive understanding of its effects requires more critical and specific testing. Particularly, it should be assessed if BTX-A actually increases muscle length range of force exertion (Lrange) and decreases muscle passive forces. Moreover, an understanding of mechanism of BTX-A effects is lacking. The goal was to address these issues experimentally and using finite element modeling. METHODS & RESULTS: Experiments: Muscles of intact rat anterior crural compartment were tested 5 days post injection [1-3]. 0.1U BTX-A in 20µl of saline (BTX-A group) or only 20µl of saline (control group) was injected into mid-tibialis anterior (TA) belly. (i) The TA was lengthened (BTX-A, n=8, body mass 312.5±14.6g; control, n=8, body mass 318.5±12.5g). (ii) The extensor digitorum longus (EDL) was lengthened and, (iii) its relative position was changed (BTX-A, n=8, body mass 315.0±6.3g; control, n=8, body mass 300.0±6.9g). In (i) and (ii) muscles other than the one lengthened and in (iii) all muscles were kept at constant length. Findings: (1) BTX-A spreads to all compartmental muscles (peak force decrease range 47.3-85.6%). (2) Force decrease is not constant, but length dependent (TA force drop increases from 46.6% to 55.9% with shortening), (3) Lrange does not increase, but can decrease (for the EDL by up to 26.1%), (4) passive forces (for all muscles, minimally three-fold) and extracellular matrix (ECM) collagen content increase, (5) intermuscular interaction gets compromised (EDL proximo-distal force differences vanishes). Model: The middle half of Linked Fiber-Matrix Mesh model was inactivated

to represent BTX-A induced partial muscle paralysis. A key effect is restricted sarcomere shortening due to muscle fiber-ECM mechanical interactions [4-5]. This is central to effects of BTX-A on muscle mechanics increasing force production capacity of activated sarcomeres, decreasing Lrange, and explains (2) and (3). If modeled ECM stiffness is increased as indicated by (4), these effects get more pronounced and become permanent, post-treatment (ceased muscle paralysis). CONCLUSIONS: Our experiments reveal remarkable new effects of BTX-A worthwhile further clinical testing. Simulations suggest that ECM adaptations can affect muscles exposed adversely during spasticity management and post-treatment leading to a stiffer muscle, with elevated tone and reduced Lrange. [1] Yucesoy et al., J Biomech Eng, 2012 [2] Ates & Yucesoy, Muscle Nerve, 2014 [3] Yucesoy et al., Muscle Nerve, 2015 [4] Turkoglu et al., J Biomech, 2014 [5] Yucesoy, Exerc Sport Sci R, 2010 TUBITAK grant: 113S293

Structural and Functional Consequences of Neurotoxin injection in a Rat Model System

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INTRODUCTION: Over the past several decades, there has been a dramatic increase in the clinical indications for neurotoxin (NT) injection that range from cosmetic to therapeutic. While the basic mechanism of action of NTs are known, the long and short-term effects on skeletal muscle are poorly understood. We have developed a rat model1 that allows us to study these effects and thus to address clinically relevant problems of neurotoxin use. METHODS: We studied muscle properties associated with injection of Botulinum toxin (onabotulinumtoxinA, Allergan, Inc.) the most commonly injected NT. We determined the effect of varying injectate dose and volume in 9 groups of animal subjects (6u/100µL, n=10), 6u/20µL (n=5), 6u/4µL (n=6), 3u/100µL (n=6), 3u/20µL (n=7), 3u/4µL (n=7), 1u/100µL (n=6), 1u/20µL (n=6), and 1u/4µL (n=10)2. We also studied the effect of NT injection alone (NT, n=8), NT injection followed immediately by 10 isometric contractions (ISO; n=9), and NT followed immediately by 10 muscle passive stretch/release cycles (PS; n=10)3. Finally, we have mapped the expression of from 4 groups (n= 4/group) at 1, 4, 12, and 52 weeks after NT injection.4 RESULTS: Regarding dose and volume, we found a

significant effect of dose (P<0.05) but no effect of volume (P>0.2) and no interaction between dose and volume (P>0.2). Regarding tissue manipulation the ISO and PS groups demonstrated significantly lower torques compared to the NT group which received no physical manipulation (p<0.05) indicating greater efficacy. Even more surprising was that the ISO and PS groups both demonstrated a significantly smaller contralateral effect compared to the NT group that received no manipulation (p<0.05) indicating a decreased systemic effect. Finally, dramatic transcriptional changes occurred at 1 week with a paradoxical increase in expression of slow and immature isoforms, activation of genes in competing pathways of repair and atrophy, impaired mitochondrial biogenesis, and increased metal ion imbalance. Adaptations of the basal lamina and fibrillar extracellular matrix (ECM) occurred by 4 weeks. The muscle transcriptome returned to its unperturbed state 12 weeks after injection. DISCUSSION: These studies confirm dramatic effects of NT on muscle and may provide guidelines to minimize systemic side effects while still producing therapeutic results. For example, since NT dose dominates its functional effects, this implies free transport throughout the rat tibialis anterior muscle. Whether this applies to human injections remains to be determined. Implications for understanding normal muscle structure-function relationships will also be discussed in the symposium.
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The effect of botulinum toxin injections on gastrocnemius muscle volume in children with spastic cerebral palsy

Adam Shortland[1], Adam Shortland[1], Adam Shortland[1], Adam Shortland[1]

[1]Guy's & St Thomas' Foundation Trust

BACKGROUND AND AIM: We investigated the effect of botulinum toxin A (BTX) on gastrocnemius volume in children with cerebral palsy (CP) 4 months after injection. We expected significant reductions in muscle volume and that change in muscle volume would be related to the dose per unit muscle volume (DUMV). METHODS: 15 ambulant children with CP (2.91-8.87 years; 3F; 4 unilateral) had BTX injections to their gastrocnemii. Doses were consistent with the European Consensus Statement. 3D ultrasound scans of the gastrocnemii were made before, and four months after,

injection. We measured change in gastrocnemii volume over this period. Muscle volumes were normalised to body mass. The dependence of change in muscle volume on DUMV and on muscle volume prior to injection was evaluated using regression analysis. RESULTS: At 4 months post-injection, there was a reduction in gastrocnemius volume (mean 15.9%, $p < 0.018$). We found no significant relationship between DUMV and change in muscle volume ($p=0.852$). However, we found a dependence of change in muscle volume on original volume ($p=0.000$, $r2 = 0.612$) with larger muscles losing as much as 40% of their volume while there was little change in the size of the smaller muscles. CONCLUSIONS: Only small doses of toxin are required to induce significant atrophy in targeted larger muscles. In smaller muscles, a combination of increased diffusion of the toxin away from the target muscle and increased non-myofibrillar content may limit the therapeutic effect of the toxin.

Muscle material properties in children with hemiplegic cerebral palsy

Sabrina Lee[1], Deborah Gaebler-Spira[1], Li-Qun Zhang[1], William Rymer[2], Katherine Steele[3]

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BACKGROUND AND AIM: Individuals with cerebral palsy (CP) tend to have altered passive muscle properties, however, quantification of material properties such as stiffness, has been limited to invasive methods such as biopsies or non-invasive measurements of muscle and joint stiffness such as torque-angle measurements, compression elastography, and tendon indentation. This talk will discuss shear wave (SW) ultrasound elastography to measure SW speed, which is related to stiffness, in vivo in individual muscles. The goal of this study was to evaluate SW speed of the medial gastrocnemius (MG) and tibialis anterior (TA) in children with hemiplegic CP over a range of ankle positions and torques. METHODS: Eight individuals (mean (SD) age: 9.4(3.7) yrs; height: 1.31(0.17) m; body mass: 33.3(12.8) kg; Gross Motor Function Classification System (GMFCS) Levels: three subjects at I; five subjects at II) participated in the study. Subjects were seated in a device (IntelliStretch rehabilitation robot) with their knee in full extension and foot strapped to a rotating footplate. SW elastography ultrasound measurements (Aixplorer, SuperSonic

Imagine) of the MG and TA muscles, as well as joint angle and torque measurements, were made with the ankle set at different angles (0° dorsiflexion (DF), maximum (DF), maximum plantarflexion (PF), and two other intermediary angles) while the muscle was passive. RESULTS: Our main findings show that SW speed in the MG and TA of the more-affected limb was 14% and 20% higher than the less-affected limb at 0° DF, respectively. At the limits of ankle range of motion, the SW speed in the TA in maximum plantarflexion was significantly higher in the less-affected limb, by 11% (p=0.006). Moreover, SW speed increased in MG and TA with increasing ankle angle, torque, and fascicle strain (linear and quadratic fit, respectively). CONCLUSION: We demonstrate that SWs travel faster in the MG and TA of the more-affected than the less-affected side of individuals with hemiplegic CP, suggesting that the affected muscles have altered material properties, specifically greater stiffness. Possible factors include increased collagen content in the extracellular matrix and other connective tissue, stiffer fibers, and titin. Our result of increased SW speed with longer muscle lengths further suggests that increased passive tension is largely responsible for the changes in SW speed rather than muscle activity or hypertonicity. Greater SW velocity was also correlated with reduced ankle range of motion, indicating that increased stiffness of the MG was limiting DF range of motion for some individuals. Use of SW elastography may provide an additional means to quantify muscle material properties in a patient-specific, non-invasive, real-time manner. Being able to characterize altered muscle material properties is important for understanding the causes of abnormal muscle function, aiding diagnosis, and guiding treatment planning.

Persistent muscle weakness and contractile material loss in a clinically relevant botulinum toxin type-a (btx-a) injection protocol

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BACKGROUND AND AIM: Botulinum toxin type-A (BTX-A) is a common therapeutic treatment modality to relax spastic muscles by preventing acetylcholine release at the motor nerve endings. Although considered safe and FDA approved, our previous studies showed persistent muscle weakness and contractile material loss following BTX-A intervention using an aggressive injection protocol that did not reflect clinical

BTX-A treatment practice. Therefore, the aim of this follow up study was to evaluate possible changes in muscle strength and contractile material in a clinically relevant BTX-A injection protocol. All experiments were performed using the quadriceps femoris musculature of New Zealand white (NZW) rabbits. METHODS: Twenty-three (n=23) NZW rabbits were divided into four groups as follow: Control saline injections (n=5); Single BTX-A injection (1-BTX-A; n=6); Two BTX-A injections (2-BTX-A; n=6), and Three BTX-A injections (3-BTX-A; n=6). BTX-A experimental group animals received an injection (3.5U/kg) unilaterally into the quadriceps femoris. Repeat injections were separated by a three months interval. Animals were evaluated six months following the last BTX-A injections. The primary outcome measured were knee extensor strength and the percentage of contractile material in the BTX-A injected muscles compared to the muscles in the Control group rabbits. Muscle strength was assessed by measuring the maximal isometric knee extensor strength obtained via femoral nerve stimulation. The percentage of contractile material was determined histologically as the area fraction of contractile material relative to the total muscle cross-sectional area. A one-way ANOVA was performed at $\alpha=0.05$. RESULTS: Six months following a single BTX-A injection, muscle strength (not shown) and contractile material (Fig. 1) were significantly reduced to 45% and 59%. Respectively, when compared to Control group rabbits. Interestingly, there was no additional loss in strength and contractile material in muscles receiving 2 or 3 repeat injections compared to rabbits receiving a single injection. CONCLUSIONS: The results of this study suggest that muscle strength and contractile material do not fully recover within six months of a clinically relevant BTX-A injection protocol, suggesting that BTX-A has long lasting adverse effects which may further compromise muscle function. Furthermore, it appears that multiple injections have an increased treatment effect without additional adverse effects, thereby allowing for prolonged reduction of spasticity without penalty to muscle structure and function. Fig 1 Histological cross-sectional image showing the percentage of muscle contractile material (H&E - red staining) and non-contractile material (white color - primarily fat and connective tissue). The amount of contractile material for Control group rabbits was 96±3.0% (top left). Following a single BTX-A injection, there was a significant reduction of contractile material for 1-BTX-A g

Intraoperative Testing of Individual Spastic Knee Flexor Muscles' Capacity to Affect Impeded Knee Joint Function in Cerebral Palsy Patients

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BACKGROUND AND AIM: Diagnostic tests and the treatment plan in spastic cerebral palsy (CP) including botulinum toxin type A administration or surgery are based on gross joint motion limitation, despite being applied to individual muscles. However, the relationship between individual muscle mechanical characteristics and the joint function is not known. Recently, we developed an intra-operative method to measure the forces of knee flexor muscles with respect to knee angle [1]. This method allows determining individual muscle's capacity to affect joint mechanics. The aim of this study was to assess (i) if mechanics of spastic semitendinosus (ST), semimembranosus (SM), and gracilis (GRA) muscles activated alone are representative of the impeded knee joint function and (ii) how simultaneous activity of an antagonistic muscle affects those mechanics. The following hypotheses seeking for reflections of muscle contracture at the joint were tested: (i) the muscle's joint range of force exertion is narrow, and (ii) high muscle forces are available in flexed knee positions. METHODS: During remedial surgery, forces of exclusively activated ST (n=7, 12 limbs), SM (n=8, 13 limbs), and GRA (n=7, 10 limbs) muscles of spastic CP patients were measured as a function of knee angle from flexion (120°) to full extension (0°). GRA muscle was tested also with added vastus medialis (VM) activation (n=6, 10 limbs). RESULTS: For most limbs, spastic muscle force-knee angle curves show only an ascending portion and for the remaining limbs the curves have also a descending portion for ST, SM, and GRA muscles [e.g., 2]. Lack of curves showing a descending portion alone indicate no narrow joint range of force exertion. Capacity of producing knee flexion forces (mean (SD): at KA=120° ST: 11.4% (21.4%), SM: 4.2% (3.4%), and GRA: 59.4% (33.3%); at KA=90° ST: 33.2% (27.5%), SM: 10.7% (9.7%), and GRA: 75.1% (28.6%)) show significant differences between muscles. However, for none of them, force production capacity in flexion was supreme to cause the apparent joint movement limitation. Yet, simultaneous activation of the VM, caused seven of the ten limbs to show availability of high GRA forces in flexed knee positions (with minimally 84.8% of peak force at 120°). A clear narrow operational joint range of force exertion was observed for four limbs [3]. CONCLUSIONS: Both hypotheses were rejected if muscles are stimulated exclusively. Therefore, individual mechanics of spastic ST, SM, and GRA muscles do not represent

impeded knee joint function. However, antagonistic co-activity does cause substantial changes in force production capacity of spastic GRA muscle. Therefore, we concluded that inter-antagonistic mechanical interaction is an important factor determining spastic muscle's contribution to impeded joint function. [1] Yucesoy C.A. et al. J Biomech, 2010 [2] Ates F. et al. Clin Biomech, 2013 [3] Ates F. et al. Clin Biomech, 2014 TUBITAK grant 113S293 is acknowledged.

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DAY 3, FRIDAY JULY 8

S.13. *Prosthetics to Orthotics: Transferable Expertise*

The state-of-the-art EMG control in dynamic orthoses

Derek Kamper[1]

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Orthoses have similar task objectives as prostheses, yet pose unique challenges due to the presence of the impaired limb. To simulate discussion during our workshop (?Prosthetics to orthotics: transferrable expertise??), I will describe current techniques employing electromyography (EMG) to control external devices, with an emphasis on applicability to orthoses. While assistive technology has become increasingly sophisticated, user control of these devices remains challenging. The human body employs billions of neurons to provide the exquisite sensoriomotor control of the limbs. Replication of this system is neither currently possible nor foreseeable. Instead, other means of signaling user intent must be found. One intuitive method involves use of a subset of the residual neuromuscular system. Electrical activity can be monitored in the central nervous system, such as with electrode arrays implanted in the cortex, or recorded in the periphery at the neuromuscular junction. The latter method, relying on EMG, has advantages in that it is less invasive and the nerves normally associated with the desired functional task can be more easily targeted. Studies employing directed reinnervation of a designated muscle with residual nerves which formerly ran to muscles which have been lost due to amputation, have noted the facility with which users can use the system[1]. Lightweight, flexible surface electrodes provide a comfortable interface for deciphering user intent. These electrodes can be embedded into the assistive device itself. As a mapping is generated between EMG activity and desired task, exact positioning of the electrodes on the limb may not be crucial. Repeatable modulation of EMG patterns specific to a task is more important than the absolute activation pattern. Untargeted electrode replacement may perform as well as targeting specific muscles[2]. Signals may, in fact, be acquired from the contralateral limb to control a device on the ipsilateral limb. EMG bandwidth can be increased by utilization of electrode arrays. For greater precision, electrodes can be placed within the body, such as by inserting into the muscle or surrounding the nerve. The implantable myoelectric sensors (IMES)[3] and the longitudinally implanted intrafascicular electrodes (LIFE)[4] have been developed to provide user control of hand prostheses. These electrodes could also be employed to control orthoses, although a number of the populations which could potentially benefit from orthoses have altered neuromuscular systems which could hinder recording and deciphering EMG signals. Such individuals may, however, derive therapeutic benefit from the use of EMG-controlled devices through the training of creating specific activation patterns. 1) Kuiken TA, et al., Prosthet Orthot Int 2004; 28: 245-253 2) Farrell TR and Weir R, IEEE Trans Biomed Eng 2008; 55: 2198-2211. 3) Weir RF, et al., IEEE Trans Biomed Eng 2009; 56: 159-171. 4) Micera S, et al., IEEE Rev Biomed Eng 2010;

Unassisted FES is all you need to regain hand function

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Orthoses have similar task objectives as prostheses, yet pose unique challenges due to the presence of the impaired limb. This is specifically the case for active orthoses. Functional electrical stimulation driven orthoses, called transcutanous neuroprostheses act with and on the impaired limb and use both remaining residual voluntary functions and elicited muscle activations. As such the impaired limb serves as actuator and is at the same time actuated. Specific challenges of FES driven limbs are: i) mechanical/wearability properties of the orthotic structure; ii) properties of the electrode interface; iii) specificities of the stimulated neural/musculoskeletal structure; iv) neuroprosthesis control challenges; and the multi-dimensionality challenge. This is particularly the case for neuroprostheses enabling hand function. The main novelty in transcutaneous neuroprostheses research in recent years was the investigation, modeling, analysis, development and application of transcutaneous FES arrays that allow a dynamic distribution of electrical fields over the limb surface. They allow an improved control over eliciting action potentials in superficial nerve branches and lead to improved limb functions. This session contribution will discuss the above mentioned challenges and show how far the field currently is from having an unassisted transcutaneous neuroprosthesis to regain hand function.

Direct mechanical control outperforms EMG control

Dick Plettenburg[1]

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BACKGROUND AND AIM: Orthoses have similar task objectives as prostheses, yet pose unique challenges due to the presence of the impaired limb. To stimulate discussion during our workshop "Prosthetics to orthotics: transferrable expertise?", I will defend the hypothesis that direct mechanical control outperforms EMG control. METHODS: The sound human arm has an excellent controllability due to a highly sophisticated network of sensors and information paths [proprioception] providing extensive feedback. In the use of prostheses most of these feedback paths are missing. This is often true for orthoses as well. For the optimal subconscious control of a prosthesis or orthoses the patient feedback present must be employed as completely as possible. This requires the use of the principles of extended physiological proprioception. RESULTS: From the control options presently available, myoelectrical control must be considered as an open loop system. It lacks by principle the feedback indispensable for the subconscious control level desired. The harnessing of body movements has the inherent ability to fully employ the principles of extended physiological proprioception. However, the present harnessing techniques fail to do so and are generally of a dreadful engineering quality. The challenge for the prosthetic/orthotic profession is to make subconscious control of prostheses and orthoses available. Therefore, research should focus on the [improvement of] control options that comply with the rules of extended physiological proprioception. By principle, myoelectrical control cannot meet these rules. Hence, any further research into myoelectrical control does not contribute to the answer this challenge. CONCLUSIONS: Improvement of harnessing techniques in combination with improvements in efficiency of prosthetic/orthotic mechanisms does answer the challenge. In addition, they have the added benefit of being lower in mass, more reliable, faster, and smaller when compared to electro-mechanical

solutions. Therefore, mechanical solutions are the better choice in prostheses and orthoses.

Surface EMG control in neurorehabilitation: experiences from EMG-driven modelling and robotic for upper and lower limb post-stroke rehabilitation

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Background: The recovery of motor function following stroke remains a challenge in neurorehabilitation. Often, the remaining impairments are associated with poor autonomy in daily life. Innovative approaches are therefore needed, employing advances in neuroengineering into clinically viable devices. Purpose: The FP7-EU project MYOSENS aims at translating technological advances in surface electromyography (sEMG) into new classes of robotic devices for rehabilitation. These devices close the sensory-motor loop on the basis of the predicted motor intention derived from residual sEMG recorded from post-stroke patients. The prediction and control may be based either exclusively on signal features or on musculoskeletal mechanical variables estimated by musculoskeletal models from the raw EMG. Methods: Musculoskeletal modelling formulations driven by sEMG were developed to bridge the neural and mechanical aspects of motor functions in vivo in the intact human. These models allow predicting the musculoskeletal response to any recordable neuromuscular behaviours (healthy or pathological). In this context, two robots (Shoulder: RehArm®, FERROBOTICS GmbH; Hand: Amadeo®, Tyromotion GmbH) were used to test the clinical effect of using sEMG closed-loop control to practice voluntary movements as rehabilitation treatment. Two feasibility studies (N=20 each) were conducted in patients with every impairment of upper limb motor function after stroke. Fugl-Meyer upper extremity (F-M UE), FIM®, Nine Hole Peg test (NHPT) and Reaching Performance Scale (RPS) were assessed before and after a therapy of 15 sessions over 3 weeks. Results: All patients enrolled completed the experiments without side effects. The shoulder treatment induced significant improvement at F-M UE, RPS and FIM. Patients with severe impairment (F-M UE < 40/66) were able to complete a comparable number of repetitions of shoulder motion as mild patients when using sEMG for control, but not when using force control. The hand treatment induced significant improvements at F-M UE, FIM, RPS

and BBT. In this case, all the patients could control the robotic devices by sEMG, but not by torque. Moreover, threshold scores of specific outcome measures could predict the ability of the individual patients to control exclusively using sEMG (RPS≥3, F-M UE≥10 points) or also with torque (BBT≥3). Conclusion: EMG can be used for controlling rehabilitative robotic devices with methods clinically feasible. The proposed EMG-based experimental treatments resulted in a significant improvement of robust clinical outcomes, indicating that EMG control is feasible for a greater proportion of patients with respect to torque control. Grants: The EU FP7 project "Myoelectric interfaces for motor control - MYOSENS" (286208).

The case for impedance control in wearable robotics

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Powered orthoses--often termed exoskeletons--have similar design and control constraints to prostheses, with the unique and important challenge of interacting with existing limb anatomy. Furthermore, exoskeleton wearers have varying abilities to voluntarily control their limbs, depending on the specific pathological application of the exoskeleton. In this talk, part of the symposium on translating prosthetic research to orthotic applications, I will defend the hypothesis that impedance control implemented in exoskeletons will provide superior performance. The rationale for this hypothesis is that impedance control enables the mathematical framework to offset the biomechanical changes that occur following neuropathologies, as well as provides a mechanism to define the impact of the additional (and often unpredictable) effort provided by the wearer. Examples will be highlighted from the prosthetics and orthotics literature, as well as the author's previous work. A common result of neuromotor impairment is a reduction in the ability to voluntarily control joint mechanical impedance. Clinically, this is known as spasticity, hypertonia, and contracture that causes changes in the velocity and position dependent joint mechanics (i.e. damping and stiffness, respectively). These changes induce unwanted joint resistance that the patient must overcome during movement. Due to accompanying weakness or hemiparesis, overcoming the additional resistance can be extremely challenging. Thus, impedance control is a promising control methodology as it enables the ability to counteract the impedance changes that occur as a result of

neuromotor injury. Classical position and torque control focus on controlling these variables directly while following a pre-determined path, driving the error in these quantities to zero. Conversely, impedance control focuses on controlling the relationship between position and torque, rather than either of these variables directly. Impedance control is often parameterized in similar terms of stiffness, damping and inertia, and changes in these parameters affect the enforced dynamics between position and torque. Using the impedance control framework, the pathologically altered joint mechanics can be appropriately compensated with the impedance parameters specified in the control system. Additionally, impedance control is advantageous because it couples and bounds the position and torque, preventing potentially unwanted or unsafe changes due to the joint effort of the wearer. Classical torque control does not restrict or depend on position, and position control does not restrict torque. However, when the existing anatomy is present and providing additional torques in parallel with the exoskeleton, traditional torque and position control cannot define the impact of the additional effort provided by the wearer. This may cause unwanted changes in torque or position that can destabilize the wearer, compromising balance and safety.

Structured panel discussion on prosthetics to orthotics: transferrable expertise

Arno Stienen[1]

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Orthoses have similar task objectives as prostheses, yet pose unique challenges due to the presence of the impaired limb. To stimulate discussion during our workshop ("Prosthetics to orthotics: transferrable expertise?"), we will invite audience participation to discuss the presented hypotheses. Below you see a list of propositions that are stated such that they evoke discussion. We will summarize the main arguments and invite the room to a structured discussion. - Derek Kamper: State of EMG control in dynamic orthoses. - Thierry Keller: Unassisted FES is all you need to regain hand function. - Dick Plettenburg: Direct mechanical control outperforms EMG control. - Elliott Rouse: Force/impedance control outperforms EMG control in orthoses. - Dario Farina: EMG control gives the most functional gain.

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S.14. Clinical applications of muscle synergies

Function and dysfunction in brain connectivity coordinating muscle synergies in humans

Jason Kutch[1]

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BACKGROUND AND AIM: The human brain is believed to simplify the control of the large number of muscles in the body by flexibly combining muscle coordination patterns, termed muscle synergies. However, the neural connectivity allowing the human brain to access and coordinate muscle synergies to accomplish functional tasks remains unknown. Moreover, dysfunction in the brain connectivity that coordinates muscle synergies may be an important component in disorders of neuromuscular control. METHODS: We define and demonstrate the capabilities of a multimodal approach to investigate brain connectivity of muscle synergies. First, using electromyography (EMG), we describe and quantify synergistic interaction among a group of muscles. Second, using functional magnetic resonance imaging (fMRI), we identify cortical and subcortical regions-of-interest (ROI) associated with activation of specific muscle synergies. Third, using transcranial magnetic stimulation (TMS), we show that different fMRI-identified ROI act as "muscle synergy access points" which activate different muscle synergies. Fourth, using resting-state fMRI (rs-fMRI), we make whole-brain maps of the functional connectivity (interaction strength during rest) of different muscle synergy access points. Finally, we associate inter-individual differences in functional connectivity of muscle synergy access points with inter-individual differences in muscle control and disease status for patients with chronic pain. RESULTS: Results for muscle synergies involving pelvic floor muscles are presented. EMG recordings verify that pelvic floor muscles are synergistic with gluteal, toe, and deltoid muscles but not finger muscles. fMRI data uncover motor cortical ROI that activate during voluntary activation of pelvic floor muscles and also activate during voluntary activation of pelvic floor muscle synergists. fMRI data also uncover motor cortical ROI specific to activation of the pelvic floor synergists. TMS experiments show that motor cortical ROI are muscle synergy access points, each activating different muscle synergies. rs-fMRI maps of functional connectivity

demonstrate that motor cortical access points to different muscle synergies have significantly different functional connectivity with distinct and distant brain regions. Finally, we show that inter-individual differences in the functional connectivity of motor cortical muscle synergy access points are associated with inter-individual differences in muscle synergy strength at the EMG level in healthy individuals, and are associated with symptom intensity and muscle synergy strength in individuals with chronic pelvic pain. CONCLUSIONS: These results suggest that proper function in human brain connectivity plays a critical role in coordinating different muscle synergies, and dysfunction in this connectivity may play an important role in chronic pain disorders.

Does modularity in post-stroke motor coordination differ in dynamic and static tasks?

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Background and Aim: Previous studies of human reaching and locomotion in stroke survivors (Cheung et al., 2009, 2012; Clark et al., 2010) suggest that the structure of muscle synergies (a coordinated pattern of activities of a group of muscles) is conserved, but the activation profile of the synergies is altered post-stroke. In contrast, our previous studies of isometric force generation (Roh et al., 2013, 2015) demonstrated that stroke induces alterations in the structure of upper limb muscle synergies. These results suggest that the underlying mechanisms of post-stroke motor performance in dynamic (reaching or locomotion) and static (isometric force control) conditions may differ from the perspective of modularity in motor coordination. To address this question, we examined the modular organization of muscle activation patterns across the time course of isometric force development, while our previous work solely focused on the averaged, stable force match phase. Methods: EMG was recorded from eight major muscles of the affected arm of eight chronic stroke survivors with severe impairment (Fugl-Meyer < 25) and both arms of six age-matched control participants, during a 3-dimensional isometric force matching task. A non-negative matrix factorization algorithm identified muscle synergies in two time windows: force ramping phase, and stable force match. Correlation coefficients between any potential pair of end-point force components

were also computed for the same time windows. Results: The same set of synergies was expressed during both phases of force generation, in both stroke and control subjects. In stroke, but not in the control, the structure of two proximal synergy patterns was altered. The atypical co-activation of the three heads of the deltoid was conserved throughout force development in the stroke group. In addition, the activation profiles of two elbow and shoulder synergies were synchronized so that the corresponding synergy pattern appeared as a merged one in stroke survivors. In both groups, all computed force correlations were significantly higher ($p<0.05$) during the force ramping phase compared to stable force generation. In stroke, a higher force directional error was observed during the force ramp phase ($p<0.05$). Conclusions: Stroke-specific muscle synergies are conserved throughout the entire duration of isometric force development. During stable isometric force generation in both control and post-stroke groups, the CNS is able to appropriately modulate the activation profile of muscle synergies to maintain the targeted force, which, in turn, decreases the corresponding force couplings and directional error. Overall, these findings indicate that stroke may induce alterations in the structure of muscle synergies in a task-specific way, while the merging of muscle synergies is common to the temporal EMG profiles of both dynamic and static motor tasks following stroke.

Neuromotor modules as markers of diseased states and progress of motor recovery

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BACKGROUND AND AIM It has been suggested that the combination of discrete motor modules is a viable framework for mechanistically understanding how the immense variety of movement patterns are generated by the CNS. In most formulations, a motor module consists of a set of time-invariant activation weights across many muscles (widely called a "muscle synergy"), and a time-varying coefficient that scales the muscle weights across time. Experiments performed using techniques ranging from multi-channel EMG recordings to optogenetics have provided evidences that support the neural origin of motor modules. If motor

modules are indeed neurophysiological entities employed by the CNS for control, characterizing their deviations in diseased conditions should not only offer insights into the underlying pathology responsible for the dysfunctional movement, but also suggest how an effective intervention may be rationally designed. At the very least, distinctive patterns of abnormal motor modules may be robust signatures of particular diseased states, and thus be potentially used as markers for diagnosing a condition, or for evaluating the progress of recovery. Here, we argue, with two examples, that abnormal patterns of either the muscle weights or temporal activations of the motor modules may serve as markers of diseased states. METHODS EMG signals and kinematics were recorded from upper-limb of adult stroke survivors (for example 1) and lower-limb of children with delayed-onset locomotion (for example 2), respectively, before and after rehabilitation. Motor modules were extracted from the signals using the non-negative matrix factorization algorithm. RESULTS The first example concerns upper-limb modules observed in stroke survivors. We have previously shown that severe post-stroke motor impairment is associated with merging of the modules' muscle weights, while the chronicity of stroke is reflected as fractionation of the muscle weights. Our preliminary results from chronic survivors undergoing rehabilitative training indicate that enhanced post-rehab motor recovery is associated with the activation of a specific module in the affected arm after rehab, one that can be regarded as a marker of post-training recovery. The second example concerns lower-limb modules observed in infants with delayed-onset locomotion, a condition with variable causes that affects up to 5-15% of newborns. We found in our pilot data that in these children, the temporal activation burst of one module was consistently time-shifted to the right relative to the burst of another module. Children responsive to physiotherapy displayed a post-rehab temporal activation pattern similar to that observed in age-matched, normally developed children. CONCLUSIONS The above two examples illustrate the potential of using either the muscle weights or temporal activations of specific modules for early detection and/or evaluation of recovery progress for different movement disorders.

Synergistic changes in muscle coordination post-stroke in a locomotor learning task

Gelsy Torres-Oviedo[1], Pablo Iturralde[1]

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BACKGROUND AND AIM: Promising studies have shown that patients post-stroke can re-learn to step symmetrically after walking on a split-belt treadmill, which moves their legs at different speeds (Reisman et al. 2013). While this is encouraging, little is known about the underlying changes in muscle activity. The latter is important to understand the actual plasticity of neural mechanisms in these patients. METHODS: We investigated changes in muscle coordination of 16 chronic post-stroke subjects and 16 sex- and age-matched controls during split-belt walking. All patients were in their chronic stage (>6 months after stroke) and had diverse motor impairments as quantified by their Fugl-Meyer scores ranging from 21 to 33. Patients experienced a typical adaptation paradigm consisting of a baseline, adaptation, and post-adaptation conditions. In the baseline and post-adaptation conditions both legs moved at the same speed, whereas in the adaptation condition legs moved at different speeds (i.e., the paretic leg moved twice as slow as the non-paretic one). We measured electromyographic activity in 15 muscles on each leg and evaluated changes in activity between the adapted vs. both the baseline and the post-adaptation conditions using Skillings-Mack test. Bonferroni correction was used to account for multiple comparisons. In addition, a measure of independence in muscle activity was obtained using principal component factorization analysis. This was done to determine if abnormal muscle synergies post-stroke were disrupted when experiencing the split-belt condition (Fig. 1A). RESULTS: We found consistent changes in muscle coordination bilaterally and not only in the sound limb. Interestingly, we observed partial spatial and temporal symmetricity in these changes. In other words, increased activity on one side was mostly matched by decreased activity on the other side (spatial symmetricity) and changes in muscle activity for each leg occurred during the same phase of the ipsi-lateral gait cycle (temporal symmetricity). Similar adaptation of muscle activity was observed in age-matched controls. Importantly, our analysis of muscle independence indicated that paretic muscles increased its independent activity during the adaptation condition compared to baseline (Fig. 1B). This suggests that patients can modulate paretic muscles independently when learning a new walking pattern on the split-belt treadmill. CONCLUSIONS: Our results indicate that walking in a novel condition, such as split-belt walking, induces changes in the paretic limb beyond the expected compensatory changes in the non-paretic limb. Moreover, our proxy for muscle

control independence suggests that co-activation of paretic muscles can be reduced during split-belt walking. Taken together, these are promising findings indicating that chronic post-stroke patients may still have the flexibility to change their muscle coordination to improve their walking despite of their cortical lesions.

Do muscle synergies change after treatments in cerebral palsy?

Benjamin Shuman[1], Marije Goudriaan[2], Kaat Desloovere[1], Michael Schwartz[3], Katherine Steele[1]

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BACKGROUND AND AIM: Cerebral palsy (CP) is a neuromuscular disorder that occurs at or near the time of birth that affects mobility and muscle control. Each individual with CP has a specific injury to the brain, which manifests as a unique set of movement impairments. Current treatments include physical therapy, pharmacological interventions such as botulinum toxin injections (BTA), and surgical options such as selective dorsal rhizotomy (SDR) and single-event multilevel orthopaedic surgery (SEMLS). Improving movement requires that treatments be tailored to each individual. However, properly tailoring treatments remains a persistent challenge and new methods are needed to quantitatively characterize muscle control for use in treatment planning. The goal of this study was to evaluate whether muscle control as measured by synergies changes after treatment and if synergies are associated with treatment outcomes in CP. METHODS: We retrospectively analyzed 174 cases of children with CP that received gait analysis before and after treatment. This study included 62 cases of BTA, 65 cases of SEMLS, and 47 cases of SDR. Electromyography data was processed using nonnegative matrix factorization which identifies a specified number of weighted muscle groupings, or synergies. Synergy complexity was taken as the total variance account for by one synergy (tVAF). Changes in gait were evaluated with the Gait Deviation Index (GDI) and dimensionless walking speed. T-tests were performed to examine whether each treatment resulted in changes in tVAF, GDI, or walking speed. Linear mixed effects models were computed to determine whether initial measures of synergies were correlated with post treatment changes in GDI or walking speed. RESULTS: There were no significant changes between pre and post gait analyses in tVAF, walking speed, or GDI for the BTA or SDR groups ($p>0.05$). The SEMLS group

showed significant changes in tVAF, walking speed, and GDI ($p<0.05$) after treatment. In the SEMLS group, walking speed decreased while tVAF and GDI were more similar to unimpaired gait after treatment (Figure 1). The linear mixed effects models indicated a correlation between pre-tVAF and post-walking speed in the SEMLS and SDR groups, as well as a correlation between pre-tVAF and post GDI in the SEMLS group ($p<0.05$). CONCLUSIONS: There were significant changes in tVAF after SEMLS which had large changes in outcomes. When there were small changes in outcome measures muscle synergy complexity did not change. Pre-treatment measures of muscle synergies were also associated with changes in gait for SEMLS and SDR suggesting that synergies may be a useful measure of motor control. Figure 1: Before vs after SEMLS treatment values of tVAF (top), dimensionless walking speed (middle), and GDI (bottom). Paired t-tests were used to compare each variable before and after treatment with significance set at $p<0.05$. tVAF and GDI improved while dimensionless walking speed did not.

Long-term training modifies the modular structure and organization of walking balance control

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Background and Aim: How long-term training affects the neural control of motor behaviors is not well understood, but may reveal previously unknown mechanisms of motor coordination and learning that could guide future rehabilitation efforts. Therefore, our goal was to determine how the structure and organization of muscle coordination patterns for walking and balance are affected by long-term training. We hypothesized that long-term training leading to skilled motor performance increases the recruitment of common muscle patterns across different motor behaviors. In lieu of searching for behavior-specific or optimal muscle patterns, generalizing the same muscle patterns across behaviors may enable rapid, reliable, and efficient identification of motor solutions. Methods: To test this hypothesis we recruited 13 professional ballet dancers (experts) and 10 untrained novices. We used muscle synergy analysis to quantify and compare the structure and organization of their muscle coordination patterns during overground walking and a challenging beam-walking task designed to assess walking balance proficiency. Results: Consistent with

our expectation that experts would have better walking balance proficiency, experts walked farther than novices on the narrow beam. During beam walking experts recruited more muscle synergies than novices, suggesting a larger motor repertoire. In contrast, the number of muscle synergies recruited during overground walking did not differ between experts and novices, but their composition did, suggesting that extended practice on one behavior (ballet) can alter the control of another (walking). Muscle synergies in experts had less muscle coactivity and were more consistent than in novices during beam and overground walking, reflecting greater efficiency in muscle output. Moreover, the pool of muscle synergies shared between beam and overground walking was larger in experts compared with novices, suggesting greater generalization of muscle synergy function across multiple behaviors. These differences in motor output between experts and novices could not be explained by differences in kinematics. Thus, they likely reflect differences in the neural control of movement following years of training rather than biomechanical constraints imposed by the activity or musculoskeletal structure and function. Conclusions: The recruitment of common muscle synergies between beam and overground walking by experts suggests that to learn challenging new behaviors we may take advantage of existing muscle synergies used for related behaviors and sculpt them to meet the demands of a new behavior rather than create de novo behavior specific muscle synergies. Therefore, successful rehabilitation outcomes may require therapies that train patients to utilize common muscle synergies across different motor behaviors rather than behavior specific motor solutions.

O.13. Muscle Physiology

O.13.1 *Passive stiffness of lumbar multifidus and erector spinae muscle fibres is decreased in ENT1 deficient mice*

Kelsey Gsell[1], Derek Zwambag[1], Cheryle Séguin[2], Stephen Brown[1]

[1]University of Guelph, [2]Western University

BACKGROUND AND AIM: Mice lacking equilibrative nucleoside transporter 1 (ENT1) develop progressive ectopic mineralization of the fibrous connective tissues of the

spine [1], which is believed to result in a stiffer spine as the disease progresses caudally with age. Experimentally induced intervertebral disc (IVD) degeneration creates a less stiff spine, and in rabbits, has been shown to increase the passive mechanical stiffness of the adjacent multifidus muscle (muscle fibres and bundles of fibres) [2]. The purpose of this study was to determine how the passive mechanical stiffness of muscle fibres and bundles changes in the paraspinal muscles of an ENT1 deficient mouse. It was hypothesized that both fibres and bundles of these muscles would be less stiff in ENT1 knockout (KO) compared to wild-type (WT) mice, demonstrating an inverse compensatory relationship of the stiffness of muscle with the stiffness of the structure to which it attaches (the spine). METHODS: Lumbar multifidus (M) and erector spinae (ES), and tibialis anterior (TA) muscles of male, littermate paired, 8 month old, ENT1 KO and WT mice (n=8 each) were harvested; 3 fibres and 3 bundles from each muscle were tested. Sarcomere length and force were recorded as each sample was rapidly stretched every 2 minutes by increments of ~0.25 μm [2]. The force at the end of every 2 minutes was normalized to the cross sectional area of the sample to give a measurement of stress which was plotted against sarcomere length. A quadratic curve was fitted to the data points and passive elastic modulus was determined by finding the tangent slope at a sarcomere length of 3.2 μm. T-tests were used to compare modulus between KO and WT for each muscle, in both fibres and bundles. RESULTS: Fibre passive elastic modulus was lower in KO compared to WT in the M and ES muscles, while TA showed no difference (Figure 1A) (p=0.0262, 0.0016, 0.3436 respectively). M, ES, and TA bundles were not significantly different between KO and WT (Figure 1B) (p=0.1223, 0.1641, 0.1410 respectively). CONCLUSIONS: Muscle fibre passive elastic modulus (stiffness) was lower in the ENT1 KO, as expected, while bundles were not. Bundles were expected to show a similar if not greater difference than fibres, as this was seen with IVD degeneration [2]. It was suggested that this was mostly due to an increase in fibrosis of the connective tissue matrix [2]. This would suggest that in the mineralized spine of the ENT1 KO, the muscle connective tissue is not impacted, but some other mechanism is responsible for causing greater stiffness of the individual muscle fibres.
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O.13.2 *High-resolution in vivo measurement of changes in architecture of the human medial gastrocnemius muscle during passive lengthening*

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BACKGROUND AND AIM: The capacity of muscles to generate force is partially determined by the arrangement of its fibres, i.e. by the muscle's architecture. Most muscles have complex three-dimensional (3D) architectures which are difficult to reconstruct with conventional methods based on 2D ultrasound images. For this study we obtained high-resolution 3D measurements of the architecture of the human medial gastrocnemius muscle at three different lengths using diffusion tensor imaging (DTI), an MRI technique that can be used to reconstruct muscle structure in 3D in vivo. METHODS: DTI scans and anatomical MRI scans were obtained from eight healthy subjects at three ankle joint angles: (1) the angle at which fascicles first start to lengthen (the slack angle, which was measured with ultrasound); (2) full ankle dorsiflexion; and (3) an angle between (1) and (2). The knee was flexed ~18°. For each joint position in each subject, DTI tractography was used to reconstruct 10,000 fibre tracts in the medial gastrocnemius. Second order 3D polynomial functions were fitted to the tracts. The curves were then linearly extrapolated until they terminated on both the deep and the superficial aponeuroses, which were reconstructed from the anatomical MRI scans. Tracts that were extrapolated by more than 30% of their initial length were excluded from the analysis. The remaining tracts were assumed to represent the course of muscle fascicles. At least 2,800 and on average 4,200 fascicles were reconstructed per muscle. The 3D pennation, length and curvature of the fascicles were calculated. RESULTS: At their shortest in vivo length fascicles were, on average, 38 mm long (subject means ranged from 31-50 mm) and had a pennation of 29° (range 24-34°) and a curvature of 8 m-1 (range 5-13 m-1). At full dorsiflexion with the muscle-tendon unit at its longest in vivo length, the mean fascicle length increased to, on average, 56 mm (range 38-69 mm) and pennation and curvature decreased to 20° (18-26°) and 5 m-1 (4-7 m-1), respectively. At the intermediate ankle angle intermediate values of length, pennation and curvature were seen. Using estimates of the total muscle-tendon length based on cadaver measurements, these measurements show that, on average, 55% of the total lengthening above the slack length occurs in fascicles. There was variation between subjects, with fascicles contributing as little as 41% or as much as 74% to the total change in muscle-tendon length. A preliminary analysis did not identify major regional variations in fascicle

lengths or changes in length during passive lengthening. CONCLUSIONS: These data represent the first high-resolution, 3D measurements of changes in architecture of the whole human medial gastrocnemius muscle during passive lengthening. The novel techniques used in this study can also be used to measure architecture of other muscles and changes in architecture during active contractions and in muscles affected by disease.

O.13.3 *Inhomogeneity of emg-and ultrasound-detected onset of voluntary muscle activation explains their inconsistent relationship*

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BACKGROUND AND AIM: Ultrasound (US) measures of muscle activation are becoming increasingly utilised in musculoskeletal research particularly to characterise the behaviour of deep muscle activation. However, contradictory conclusions have been observed when evaluating the behaviour of muscles with either US or electromyography (EMG), for instance, changes in the behaviour of the transversus abdominis muscle in people with low back pain. The aim of the study was to examine the influences of (a) regional heterogeneity of EMG and US onset and (b) contraction speed on the difference between EMG- and US-measured activation onsets. METHODS: 28-channel high-density surface EMG with an electrode transparent to US and M-mode US were used to measure the onset of voluntary biceps brachii activation. Isometric elbow flexion was performed in 20%, 30%, 50% and 70% MVIC on a Biodex by 10 healthy young men. The first EMG onset, EMG onset at the US transducer and M-mode US-measured muscle motion onset were determined using computed and visual detection. Onset differences and correlations with EMG between-channels onset variation and rate of torque development were statistically evaluated. RESULTS: EMG onset at the US transducer was detected AFTER motion onset in 44% of trials based on computed detection of the onset and 79% based on visual detection of the onset. Multi-channel EMG indicated substantial onset heterogeneity; between-channel standard deviation was 73 ms and 28 ms (median) for the computed and visual analysis of onset detection, respectively. M-mode US

indicated additional onset differences between superficial and deep regions of the biceps brachii. Differences between EMG- and US-measured onsets increased with higher onset heterogeneity (computed: rho= 0.242, P< 0.01, visual detection: rho= -0.392, P< 0.001). Onset heterogeneity was markedly influenced by contraction speed (computed: rho= -0.471, P< 0.001, visual detection: rho= -0.652, P< 0.001). CONCLUSIONS: Inconsistency exists between EMG onset and muscle motion onset detected with US. Muscle activation elicits muscle motion that is transmitted through the muscle, which may be detected before EMG onset in other regions of the muscle. US-measured onset of myomechanical activation provides a viable, non-invasive assessment of muscle activity, however not a simple substitute for EMG. Caution should be taken when comparing results from EMG and US studies which evaluate the behavior of muscles.

O.13.4 ***Feasibility of quantitative uterine motion analysis by ultrasound speckle tracking outside pregnancy***

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Background and aim: Boosted by the modern trend in postponing conception, the number of women facing infertility problems is considerably increasing. Many couples are therefore referred for in vitro fertilization procedures. Despite representing the most advanced option, in vitro fertilization still counts for a low success rate of about 30%. There is evidence that uterine movement may play an important rule influencing fertilization outcomes. Until now, no objective means of measuring uterine movement is available. Therefore, in this work we present the first method for quantitative analysis of the uterine motion and strain. Methods: Given its widespread availability and cost effectiveness, ultrasound imaging is employed for the analysis. In particular, a speckle-tracking algorithm has been implemented that is based on block matching by normalized cross correlation. Weiner deconvolution is used to regularize the image resolution (speckle size) prior to speckle tracking (see Figure 1), and correlation filtering is adopted to improve the method reliability. The value of the cross correlation peak was evaluated to optimize block size and image oversampling ratio. The search area was based on the maximum observed velocity. The method feasibility was tested in vitro as well as for its ability to distinguish between active and non-active phase of a natural menstrual cycle in six women. An ultrasound scanner Accuvix 20 (Samsung-Medison) equipped with a transvaginal EC4-9IS probe was employed for the acquisition. Two pairs of sites were manually defined on the uterine muscle and automatically tracked for four minutes (see Figure 1). Sites close to the fundus were chosen due to the higher activity of this region. Standard deviation (SD) and mean frequency of the strain and distance between these sites were the features extracted and evaluated for classification. Results: The extracted motion features permitted successful separation between active and non-active phase of the natural menstrual cycle. In particular, SD of the measured distance between the tracked sites showed a significant difference between the two phases ($p<0.05$ by paired, double-tailed, Student t-test). Conclusions: Quantitative uterine motion analysis is feasible. Additional motion/strain features can be considered in the future for the analysis. Moreover, 3D imaging will be employed to avoid block decorrelation due to out-of-plane motion. More in general, extensive validation is necessary to show the clinical value of the proposed method.

O.13.5 *Three Different Cell Types Produce Collagen During Skeletal Muscle Fibrosis*

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INTRODUCTION: The extracellular matrix (ECM) of tissues and organs provides structural support and unique niches for resident cells. However, identities of the cells responsible for creating specific ECM niches have not been determined. The identity of these cells becomes important in disease when ECM changes result in muscle fibrosis and subsequent increased stiffness and dysfunction. Here we describe a novel approach to isolate and identifying cells that maintain the ECM niches in both healthy and fibrotic muscle. METHODS: A model of muscle fibrosis (nesprin-desmin double knockout [DKO] mouse [1]) was crossed with a mouse line expressing GFP under the control of the collagen-α1 (I) promoter [2]. Fluorescence activated cell sorting (FACS) was used to isolate GFP%2B cells from adult muscle. Antibodies were used against CD31, CD45, α-7 integrin, and Sca-1 to subdivide the mononuclear cell population. GFP%2B cells in wild-type (WT) (n=16) and DKO (n=14) mice were identified as either muscle progenitors ("SMP"= CD31-, CD45-, Sca-1-, α-7 integrin%2B) or fibro/adipogenic progenitors ("FAP" = CD31-, CD45-, Sca-1%2B, α-7 integrin-). Remaining cells were considered to be fibroblasts (FB). To characterize each cell population, RNA was isolated and RNA sequencing performed on Illumina Hi-seq 2500. RESULTS: The GFP%2B cell population in both genotypes was composed of 50% FAP, 20% of SMP and 30% of FB cells. A significant increase in GFP%2B cells/muscle mass was found in DKO mice (1,506±58 GFP%2B cells/mg muscle) compared to WT mice (657±81 GFP%2B cells/mg muscle; $p<0.001$). While the number of GFP%2B cells increased in DKO mice, the proportion of FAPs, SMPs, and FBs did not change, demonstrating that all three populations participated in the fibrotic response. RNAseq revealed differential expression of ECM genes among the three cell types. Differential gene expression of SMPs, FAPs and FBs in WT and DKO animals demonstrated distinct roles for each cell type in ECM production. FBs showed elevated expression of fibrillar ECM proteins. FAP cells had elevated expression of basal laminal ECM proteins. Finally, SMP cells had elevated expression of a few genes important for the satellite cell niche. DISCUSSION: These data demonstrate a 130% increase in collagen I producing cells compared with WT in fibrotic model. Furthermore, our data demonstrate a significant increase in all three collagen producing cell populations, while the GFP%2B cell composition generally remained the same between WT and DKO. These findings suggest that ECM production is a coordinated effort among different cell types to achieve a fully functional composite of ECM proteins. Furthermore, during fibrosis the tissue responds by increasing the production of all cell types, and thus the amount of each ECM niche. REFERENCES: 1. Chapman et al. Hum. Mol. Gen., 23:5879-5892, 2014. 2. Yata et al. Hepatology, vol. 37:67-76. 2003.

O.13.6 *Functional Relevance of Epimuscular Interactions at Forearm: In vivo Assessments with Ultrasound Elastography*

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BACKGROUND AND AIM: Lateral transmission of forces through epimysia (epimuscular myofascial force transmission; EMFT) is known for in situ animal muscles to substantially affect passive as well as active force production [1]. Recently, epimuscular interactions were reported for resting human muscles in vivo [2]. However, the existence of EMFT and its functional relevance in active human muscles are not yet clear. Shear wave elastography (SWE) is an ultrasound-based technique to evaluate muscular stiffness. The elastic modulus value obtained with this method is strongly linearly related to muscle force [3]. Therefore, SWE would provide a unique opportunity to delineate EMFT non-invasively. The aim of this study was to assess the functional relevance of in vivo epimuscular interactions on forearm in active condition by using SWE. Following hypotheses were tested: (i) Activation of an elbow flexor, brachioradialis (BR) changes the forces at wrist joint and elastic modulus of a wrist flexor muscle, flexor carpi radialis (FCR). (ii) Voluntary activation of wrist flexor muscles affects elastic modulus of an elbow flexor, BR. METHODS: 6 healthy males (27.9 ± 3.4 years old) participated. After securing the elbow and wrist joints, (i) BR was submaximally stimulated by surface electrodes with a constant current (50Hz, 10-15mA) for 3 sec and (ii) wrist flexors were voluntarily contracted at 25% and 50% of maximum voluntary isometric contraction (MVC). EMG and elastic modulus values of BR and FCR as well as the wrist torque were recorded for both conditions at 80, 60, 40, 20, 0 (=full extension) degrees of elbow angles. Root Mean Square (RMS) of EMG data was calculated. RESULTS: (i) Stimulation of BR caused an increase in wrist flexion torque by 22.8N ± 5.1N (24.0% ± 4.3% of wrist MVC) on average. Elastic modulus of not only activated BR (60.4% ± 14.6%) but also distant FCR (54.2% ± 6.0%) muscle increased significantly regardless of elbow angle. (ii) During voluntary wrist flexion, elastic modulus of a wrist flexor, FCR significantly increased by 67.9% ± 7.0% and 78.2% ± 5.4% (Figure 1A) whereas the EMG RMS values increased by 17.8% ± 13.8% and 32.6% ± 17.8%, at 25% and 50% of MVC respectively. Elastic modulus of BR increased by 48.7% ± 21.3% and 74.0% ± 7.9% as well (Figure 1B) while the increase in the EMG RMS values increased only by 2.0% ± 1.1% and 6.5% ± 4.3% at 25% and 50% of MVC respectively. CONCLUSIONS: Both of our hypotheses were supported. FCR muscle showing substantial increase of stiffness during BR stimulation clearly reflects force transmission from the latter to the former. It is also concluded that considerable amount of EMFT exists in forearm during voluntary contractions as well. Wrist flexion deformity is one of the major problems in neuromuscular diseases, and our study suggests considering elbow flexors in the treatment plan. [1] Huijing P.A. J Biomech, 1999. [2] Yaman A. et al. J Biomech Eng, 2013. [3] Hug F. et al. ESSR, 2015.

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O.14. Movement Disorders

O.14.1 *A startling acoustic stimulus influences initial and late phases of postural responses differently in people after stroke*

Jolanda Roelofs[1], Milou Coppens[1], Nicole Donkers[1], Jorik Nonnekes[1], Vivian Weerdesteyn[1], Alexander Geurts[1]

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BACKGROUND AND AIM: Rapid postural responses are essential to recover from balance perturbations and prevent falling[1]. Although postural responses are delayed after stroke[2], a startling acoustic stimulus (SAS) can accelerate the initial phase of planned postural responses (StartReact), presumably by direct activation of the reticospinal tract[3]. We aimed to investigate whether in people after stroke initial and late phases of postural responses are similarly facilitated by a SAS. METHODS: Twelve people with chronic stroke and 12 healthy controls of similar age were included. Participants received 16 support-surface translations (2.0 m/s^2) in the forward direction and were instructed to respond with a single backward step. Four trials contained a SAS (120 dB) simultaneously with the start of the translation. Using surface EMG, we determined onsets of tibialis anterior (TA) and rectus femoris (RF) bilaterally to study differences in the initial response phase between SAS and non-SAS trials, between groups and between the paretic and non-paretic leg. To study the late response phase, we determined biceps femoris (BF) onsets of the stepping leg and step onsets (using 3D motion analysis). We conducted a repeated measures ANOVA for all analyses. RESULTS: No differences in TA and RF onsets were found between the non-paretic leg and controls for non-SAS trials (TA:140±14 vs. 143±10 ms; RF: 149±9 vs. 149±15 ms) and SAS trials (TA: 118±25 vs. 127±20 ms; RF: 130±16 vs. 129±19 ms). The SAS accelerated TA and RF onsets compared to non-SAS trials ($p<0.01$) in both groups. In people after stroke, TA onsets were similar between legs. In contrast, RF onsets of the paretic leg (non-SAS: 165±13 ms; SAS: 147±36 ms) were delayed compared to the non-paretic leg ($p=0.043$). With regard to both legs, a uniform SAS effect was found for TA and RF onsets ($p<0.05$). In the late response phase no SAS effect was present for BF or step onsets. However, we found a trend towards a group*SAS interaction (BF: $p=0.068$; step: $p=0.057$). In people after stroke,

BF and step onsets did not differ between SAS and non-SAS trials (BF: 189±40 vs. 184±26 ms; step: 315±40 vs. 313±29 ms), whereas in controls the onsets were facilitated by the SAS (BF: 174±34 vs. 192±27 ms; step: 291±32 vs. 305±28 ms). CONCLUSIONS: The SAS accelerated reaction times of initial postural responses irrespective of group, whereas it did not facilitate late postural responses in people after stroke. These results confirm intact reticulospinal motor control of proximal and distal leg muscles mediating the initial postural responses. In the late phase, however, reticulospinal control appears less potent after stroke. The reticulospinal tract might thus be less able to compensate for defective corticospinal control of stepping responses. REFERENCES: [1]Maki & McIlroy. Age Ageing, 2006;35(Suppl 2):ii12-ii18 [2]Weerdesteyn et al. J Rehabil Res Dev, 2008;45(8):1195-1214 [3]Nonnekes et al. J Neurosci, 2014;34(1):275-81

O.14.2 ***Evaluations of wrist spasticity post stroke***

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BACKGROUND AND AIM: Spastic hypertonia is a major source of disability in stroke. The increased mechanical resistance to passive movement can be due to hyperactive reflexes and/or to nonreflex changes in muscles and connective tissues. All these changes may contribute to the increased resistance in passive movement of spastic limbs, and whether each of these components (tonic and phasic stretch reflex, elastic stiffness, and viscosity) is enhanced in spastic limbs or not is not clear. The goal of this study was to evaluate both reflex and nonreflex changes in stroke survivors' wrist through in vivo experiments under passive (relaxed) condition. METHODS: Eleven stroke survivors (mean (SD) age: 58.2(8.0) yrs; sex: 4F/7M; impaired side: 7R/4L; stroke duration: 9.6(7.5) yr; height (HT): 1.74(0.07) m; body mass (BM): 94.3(22.4) kg; Modified Ashworth Scale: 2.1(0.9); Deep Tendon Reflex: 1.8(1.0)) and 11 age-, HT-, BM-, and sex-matched controls (age: 51.9(9.5) yr; sex: 4 F/7M; dominant arm: 11R; HT: 1.71(0.1) m; BM: 77.6(16.8) Kg) participated in the study. With forearm fixed to a bench, the subjects' hand was attached to a rotating arm of a portable wrist robot. First, the Flexor Carpi Radialis (FCR) tendon was tapped with an instrumented tendon

tapper to measure a tapping force at 0° flexion, with FCR and Extensor Carpi Radialis (ECR) EMG measured. Then, the wrist was extended at 4 different constant speeds (5, 90, 180 and 270°/s) passively by the robot. With no FCR and ECR activities at 5°/s, the corresponding wrist torque was used to calculate wrist elastic stiffness. At the higher speeds, the first 50 msec data were used to calculate viscosity and inertia, and the difference between the total toque and nonreflex torque components was used to calculate the reflex-mediated components. RESULTS: Stroke survivors showed significantly higher tendon reflex gain (4.8(3.8) mm) than the controls (2.2(1.4) mm; p=0.044) and longer relaxation time (from the impulse response peak to 50% decay; 115.7(67.3) msec vs. 72.5(43.4) msec; p=0.044). Stroke survivors showed higher stiffness (2.9(1.6) Nm/rad vs. 0.6(0.2) Nm/rad; p<0.01), and higher viscosity (0.09(0.05) Nm/rad/s vs. 0.03(0.01) Nm/rad/s; p<0.01). The control group showed no reflex response. Slope of the patients' reflex torque with respect to the flexion angle (2.0(1.6) Nm/rad) was significantly higher than zero (p<0.01). Stroke survivors' maximum reflex torque at the 90°/s extension (1.5(1.3) Nm) was significantly smaller than that at 180°/s (1.9(1.6) Nm; p=0.021) and at 270°/s (2.3(1.7) Nm; p<0.01). CONCLUSIONS: A unique and practical method was developed to determine changes of the various reflex and nonreflex components at the wrist of stroke survivors. It provides us several quantitative measures that can be used to evaluate reflex and nonreflex changes post stroke accurately, provide insights into underlying pathological mechanisms, and potentially guide rehabilitation treatment.

O.14.3 ***Coordination of deep hip muscle activity is altered in symptomatic femoroacetabular impingement***

Laura Diamond[1], Wolbert Van den Hoorn[2], Kim Bennell[1], Tim Wrigley[1], Rana Hinman[1], John O'Donnell[3], Paul Hodges[2]

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BACKGROUND AND AIM: The prevalence of symptomatic femoroacetabular impingement (FAI) appears to be increasing, yet the associated physical impairments remain poorly defined. FAI is a morphological hip condition common in young active adults that can cause joint pain and stiffness, muscle weakness, impaired function, and eventually hip osteoarthritis. Evidence of abnormal hip biomechanics during

walking in symptomatic FAI is limited. Hip muscle activity during gait has not been investigated but may provide further insight into the physical impairments of this patient population. This study aimed to analyse muscle synergies (i.e. patterns of activity of groups of muscles activated in synchrony) during gait to compare coordination of deep hip muscles between individuals with and without symptomatic FAI. METHODS: Fifteen individuals (11 males) with symptomatic FAI (clinical examination and imaging) and 14 age- and sex-comparable controls without morphological FAI on magnetic resonance imaging underwent testing. Intramuscular fine-wire and surface electrodes recorded electromyographic activity of selected deep and superficial hip muscles. A non-negative matrix factorization algorithm extracted three synergies which were compared between groups. The FAI group synergy vector was used to reconstruct individual electromyography patterns. Patterns were also reconstructed with the control group synergy vector. The total variance accounted for (VAF) and the VAF of each individual muscle were calculated from the reconstructions and compared between groups using independent t-tests and Mann-Whitney U tests where required ($P<0.05$). RESULTS: Groups were comparable for age, BMI, sex, dominant leg tested and spatiotemporal gait variables. VAF by three synergies was less for the control (94.8 (1.4)%) than FAI (96.0 (1.0)%) group ($P=0.03$). VAF of obturator internus (OI) was significantly higher in the FAI group ($P=0.02$). VAF of the reconstructed individual electromyography patterns were significantly higher for the FAI group ($P<0.01$), regardless of the group vector used for reconstruction. VAF of quadratus femoris (QF) was reduced to a significantly greater extent in controls ($P=0.04$). CONCLUSIONS: Coordination of deep hip muscles in the synergy related to hip joint control during early swing differed between individuals with and without symptomatic FAI. The control group demonstrated higher inter-subject variability with respect to this synergy than the relatively homogeneous pattern of those with FAI. This was most apparent for activation of OI and QF, which are important hip external rotator muscles. Although the implications of these findings for symptoms and function are not yet clear, they could plausibly be related to enhanced protection for the hip, but with possible long-term consequences. Future studies should examine patients prospectively and post-operatively to establish whether treatments targeted at these features would be beneficial.

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O.14.4 *Trunk neuromuscular patterns in recovered low back injury individuals differs between those who do and do not reinjure at one-year follow up*

Cheryl Hubley-Kozey[1], D Adam Quirk[1], Daniel Trudel[2]

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BACKGROUND AND AIM: Delayed offset of trunk muscles[1], and poor proprioception are risks for low back injury (LBI)[2]. Since neuromuscular patterns are altered in those recovered from a LBI[3], we hypothesized that those with impaired feedback control would be more likely to reinjure following a LBI. Our objective was to establish if neuromuscular patterns during a dynamic leg loading task in those recovered from a LBI would differ between those who reinjure at one-year follow up. METHODS: Sixty-three recovered LBI participants (4-12 weeks post injury with minimal pain and disability) were recruited. Lying supine, participants performed 3 trials of a leg loading task, timed to a 4 second count, while instructed to minimize pelvic motion (Figure). Surface electromyograms (EMG) were collected from 24 trunk muscle sites (12 abdominal and 12 back extensors) at 1000Hz. EMG were full-wave rectified, low-pass filtered (6 Hz), time normalized to 100% and amplitude normalized to maximum voluntary isometric contractions[3]. EMG ensemble-average waveforms were calculated for each muscle site and participant. Temporal features were captured using principal component (PC) analysis models constructed separately for abdominal and back. Participants were separated as reinjury (RE) or no-reinjury (NoRE) based on 1 year follow-up (self-identified LBI limiting activity for>3 days). Mixed model ANCOVA (group, muscle, covariates: age, sex & mass) were conducted on PC scores. Tukey HSD post-hoc analyses were performed. RESULTS: Reinjury data were collected in 51 participants (24 RE). For the abdominals, five PCs captured 95% of the total variance; PC1, 4 & 5 captured group main differences ($p<0.001$), see figure. PC1 found RE had overall higher activation amplitudes than NoRE. PC4 captured that RE had higher activation following left leg lift relative to activation at the beginning of left leg lower. PC5 captured that RE had higher activation near the end of left leg lower relative to end of left leg lift. No group differences were found for back PCs ($p>0.05$). CONCLUSIONS: Higher activation (PC1) in RE, could reflect reduced abdominal strength or an attempt to increase trunk stiffness. Temporal differences while modest showed differential responses to changing external moments between groups. Higher activation and delayed offset (left leg lift) suggests

an exaggerated response to the changing sagittal plane moment in the RE group (PC4). Higher and prolonged activation during late left leg lower (PC5) may compensate for the reduced activation at the beginning of left leg lower. These data suggest those that reinjure may have impaired feedback requiring exaggerated responses to periods of the task with increased external moments (Figure), a finding consistent with risk of first time LBI[1 2]. Hence abdominal neuromuscular patterns may be useful to predict reinjury. 1) Cholewicki et al, JOSPT 2002; 2) Claeys et al, JEK 2015; 3) Moreside et al, Arch Phys Med Rehab 2014

O.14.5 ***Extrinsic finger muscle stiffness contributes substantially to increased passive stiffness of the wrist and finger joints in chronic hemiparetic stroke individuals: A Pilot Study***

Benjamin Binder-Markey[1], Julius Dewald[1], Wendy Murray[1]

[1]Northwestern University

BACKGROUND AND AIM: Both the neural impairments and increased passive stiffness of the joints in the hand [1,2] associated with chronic hemiparetic stroke make hand opening exceedingly difficult. To aid in the development of rehabilitation interventions, we aim to determine which musculoskeletal structures contribute to increased stiffness about the wrist and fingers post-stroke, something no previous study has evaluated. METHODS: Passive torques about the wrist and four MCP joints were quantified in the paretic limb of 2 males (55 & 66 yrs, 6 & 16 yrs post-stroke) with moderate to severe hand impairments associated with chronic stroke (CMSA-Hand: 3 and 2, and FMA-UE: 24 and 14). Torques were quantified throughout each joint's range of motion using a custom device, the PIP & DIP joints were splinted. EMGs were monitored to ensure the muscles were passive. Torque data for each subject were fit to an exponential analytical model, designed to theoretically separate the torques contributed by the extrinsic finger muscles from other, lumped, single-joint structures.[3] Passive stiffness, the derivative of the analytical model, was then compared to comparable data from the non-dominant limb of 2 healthy males (25 & 28 yrs). RESULTS: Passive stiffnesses quantified in two chronic stroke subjects was greater than that of two healthy subjects. (MCP: μ_{stroke} = 1.63Ncm/° vs $\mu_{healthy}$ = 0.37Ncm/°; Wrist: μ_{stroke} = 2.79Ncm/° vs $\mu_{healthy}$ = 0.67Ncm/°). Passive stiffness of the extrinsic finger muscles were higher in the two stroke subjects (Fig. 1a). No

difference was observed for the lumped, single-joint structures about the MCP joints (ligaments, capsule, & intrinsic hand muscles; Fig. 1c). Passive stiffness of the single-joint structures about the wrist (ligaments, thumb and wrist muscles) were larger in the stroke subjects (Fig. 1b). CONCLUSION: Within our pilot study the stiffness of the extrinsic finger muscles contributed substantially to increased total passive joint stiffness observed at wrist and finger joints in chronic stroke. In contrast, the combined passive stiffness of the intrinsic hand muscles and MCP joint structures post-stroke was comparable to young, healthy males. Understanding how different musculoskeletal structures contribute to increase passive stiffness in the hand and wrist will influence the development of appropriate rehabilitation interventions and devices. ACKNOWLEDGEMENT: NIH-NIBIB T32EB009406; NIH 1R01HD084009-01A1 Dewald/ Murray (PIs); Feinberg School of Medicine Dean's Dual Degree Scholar Award; and NUPTHMS 1. Kamper, DG, et al. Arch Phys Med Rehabil. 2006;87(9):1262-1269. 2. Kamper, DG, et al. Muscle Nerve. 2003;28(3):309-318. 3. Knutson, JS, et al. J Biomech. 2000;33(12):1675-1681.

O.14.6 ***Humeral rotational capabilities of stroke survivors and pattern recognition of intent during shoulder tasks***

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BACKGROUND AND AIM: Abnormal movement synergies exist in the stroke surviving population, but humeral internal (IR) and external (ER) rotation has not been explored to the same extent as other components of the synergies. It is unknown how independently humeral rotation can be controlled from other shoulder motions. There are two aims of this study; firstly to quantify the internal and external humeral rotation capabilities and their role in the common synergy patterns seen after stroke; secondly to investigate if user intent can be decoded from muscle activation patterns during single and dual shoulder-tasks. It is hypothesized that individuals with stroke will have an impaired ability to operate outside of this pattern, especially at higher amounts of effort. Longer term, these results may be important to develop control for a powered orthosis to help stroke survivors broaden their functional capability. METHODS: Using an isometric upper-extremity device instrumented with a 6-degree

of freedom (DOF) load cell, maximal torque generation capabilities of 21 stroke survivors and 4 healthy control subjects were recorded in four DOF's (shoulder abduction/adduction, flexion/extension, IR/ER, and elbow flexion/extension). During these maximal voluntary contraction single-DOF tasks, electromyographic (EMG) signals were recorded from eight ipsilateral upper extremity muscles. User intent was decoded from the EMG using linear-discriminant analysis (LDA). RESULTS: The survivors of stroke in this study have the torque generating capability to move their arm in external and internal rotation. But, as seen in Figure 1a, ER often occurred concurrently with shoulder abduction and IR often occurred concurrently with shoulder adduction. An examination of the LDA classification accuracy between tasks showed difficulties in discriminating between these "within synergy" movements with classification accuracies dropping from ~95% to ~80% (Fig 1b). An LDA of the control subject EMG also had difficulty discriminating between these same movements. CONCLUSIONS: Stroke survivors have the torque generation ability to rotate their humerus, however rotational control in this task is coupled with shoulder abduction/adduction in both populations. The pattern recognition system has the capability to decode most shoulder movements with high accuracy; however there is some confusion between within synergy movements. Therefore, further testing is now being conducted using a dual-task methodology to decouple these DOF's and better target the specific movement impairments in individuals with stroke. These experiments will characterize the humeral rotation isometric torque generation capabilities of hemiparetic shoulders and examine synergy induced changes during different levels of shoulder abduction and adduction effort.

S.15. ***Multichannel EMG: decomposition and other applications***

Convolutive source deflation significantly improves convergence of blind motor unit identification from surface electromyograms

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BACKGROUND AND AIM: Several algorithms have been proposed for decomposition of high-density surface electromyograms (hdEMG) [1,2]. Many of them model hdEMG as convolutive multiple-in-multiple-out (MIMO) system with motor unit (MU) discharges as inputs, MU action potentials (MUAP) as impulse responses and EMG signals as outputs. Sequential MU identification is then applied by identifying one MU filter per single decomposition run and applying it to hdEMG signals. This MIMO model is very powerful as it implicitly resolves MUAP superimpositions and accounts for arbitrary MUAP changes in different EMG channels. However, it is also redundant as it uses ~30 delayed replicas of the same MU discharge pattern to describe convolutions with MUAPs. As a result, decomposition techniques reconstruct several delayed versions of the same MU discharge pattern, what makes them computationally suboptimal. METHODS: Subtraction of identified MUAP trains from the hdEMG signals has been proposed [2] to deal with this problem, but this approach is sensitive to accumulation of errors. Source deflation with Gram-Schmidt orthogonalization (GSO) of MU filters is also possible, but this orthogonalization only protects against convergence to exactly the same replica of MU discharge pattern. In this study we propose an extension of GSO scheme to convolutive MIMO model. Array of 5 by 12 electrodes (LISiN, Italy) was used to record hdEMG during different contraction levels (from 10% to 70% of MVC in steps of 10% of MVC) of tibialis anterior muscle in 6 healthy subjects. Monopolar signals were bandpass filtered (20-750 Hz), amplified and sampled at 2048 Hz with 12 bit resolution (OT Bioelettronica, Italy). Recorded signals were decomposed twice, by Convolution Kernel Compensation (CKC) [1] algorithm with standard GSO and by CKC algorithm with novel orthogonalization. Pulse-to-Noise Ratio (PNR) [1] was used to assess the accuracy of MU identification. RESULTS: CKC with novel orthogonalization identified 4.6±0.7, 8.2±2.1 and 13.7±4.6 MUs with PNR>30 dB (accuracy>90%) in the first 5, 10 and 20 decomposition runs, respectively. In the same conditions, CKC with GSO identified 4.4±1.1, 5.3±1.9 and 5.4±1.9 MUs. In 10 and 20 decomposition runs, the number of identified MUs was significantly lager with new orthogonalization scheme than with GSO (Wilcoxon signed rank test, $p<0.0001$). CONCLUSIONS: Proposed convolutive orthogonalization efficiently protects against multiple convergences to the same MU discharge pattern and is not sensitive to errors in MUAP train estimation. As such, it effectively reduces the decomposition time and boosts the number of identified MUs. Both aspects are of paramount importance in studies of MU populations. This study was supported by Slovenian Research Agency (projects L5-5550 and J2-7357). [1] Holobar A et al. 2014, J Neural Eng. 11(1):016008 [2] Chen

M, Zhou P 2016, IEEE Trans Neural Syst Rehabil Eng. 24(1):117-27, doi: 10.1109/TNSRE.2015.24120

High-density surface electromyograms: do they sample representative muscle active?

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The possibility of sampling the activity of muscles other than that of interest with surface electrodes (i.e., cross-talk) has been of marked concern in the scientific and clinical community. Less disseminated though is the possibility of sampling EMGs from unrepresentative muscle regions. Specifically, users of surface electromyography are rarely aware that some, or even most, of the active muscle fibres might locate outside the pick-up volume of electrodes. Under these circumstances, muscle activity may be not genuinely represented in the detected signals and, consequently, attributing changes in EMG features to physiological muscle changes may be not possible. The issue of representativeness in surface EMG, although opposite to cross-talk and apparently incipient, is equally critical. In a continued attempt to attenuate cross-talk, manufacturers have reduced inter-electrode distance and electrode size considerably, further biasing the representation of muscle activity in the EMGs. On one hand, collecting surface EMGs with a grid of electrodes rather than with the conventional bipolar electrodes provides a more global muscle view. On the other hand, it is often not viable to use grids of electrodes to sample activity from different muscles. Ideally, one could propose the bipolar electrodes must be sensitive to the most possibly localised changes in muscle activity whereas grids of electrodes must resolve them. In both cases, whether EMGs fully represent muscle activation depends not only on electrodes? pick-up volume but also on how locally changes in muscle activity might manifest? The size and the location of the active muscle volume are currently not predictable. Also unclear is the relation between the location and size of active muscle volume and its associated spatial representation in the surface EMG. Compelling evidence from different research centres suggests the spatial distribution of muscle activity depends on the task performed, force direction, muscle architecture, fatigue, contraction intensity, and on several other factors. Anthropometric differences, although apparently

undocumented, likely account for the relative spatial changes in EMGs between individuals. It appears obvious after all that a unique system of electrodes, be it bipolar or high-density, would rarely suffice for the unambiguous sampling of representative activity from different muscles. Identifying the causes and consequences of not sampling representative muscle activity with surface electrodes, as dealt with in this speech, is a potentially promising approach for the design of systems able to circumvent this issue.

Topographical characteristics of motor units of the complete facial musculature determined by means of high-density surface EMG.

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INTRODUCTION: The facial musculature participates in many important functions such as speech, food intake and mediation of emotional and affective states. Therefore, functional investigation of the facial motor system by means of conventional surface EMG techniques is relevant in several medical disciplines. Moreover, systematic topographical data on the facial musculature at a single motor unit (MU) level was lacking. AIM: To topographically characterize the MUs of the upper, midfacial and lower facial muscle subcomponents including the periorbital and lip musculature. METHODS: High-density surface EMG (HDsEMG) was recorded in five separate measurement sessions from 21 individual facial muscle subcomponents using 0.3mm-thin multi-electrode grids with a maximum of 256 channels. In total, thirty-nine healthy adult subjects were trained to be able to perform slight to moderate (attempted) selective contractions of investigated muscle subcomponents. Multichannel motor unit action potentials (MUAPs) were decomposed by convolution kernel compensation technique (Holobar et al., 2007). For each MUAP, the initiation and propagation of the potential were topographically identified in the time sequence of the interpolated monopolar amplitude maps to determine motor endplate zones and muscle fiber directions. RESULTS: Generally, our findings confirm previous anatomic studies demonstrating high inter-individual variability in the anatomy of the facial musculature with absence of certain muscle subcomponents in some individuals and varying fiber architecture and innervation zone locations. Decomposed MUAPs reveal the distinctive topographical characteristics of facial MUs, such as overlapping territories of MUs belonging to different muscles and the occurrence of asymmetrically located endplate zones within single muscles. In the upper facial muscles as well as the orbicularis oculi we found widely distributed motor endplate locations over the muscle. In the other subcomponents, clustering of endplate zone locations has been found at least to a certain extent with more or less varying locations of endplate clusters between individuals. CONCLUSIONS: Results of this series of studies are unique with regard to the fact that topographical information has been obtained at the level of the smallest functional neuromuscular units (i.e., the MUs) from a relatively large group of healthy individuals without dissection of human cadavers. This allows the use of the individual results for optimizing functional investigations, e.g. establishing electrode placement guidelines for speech and psychophysiologic research, and for endplate-targeted Botulinum neurotoxin injection with reduced side-effects. Beyond this practical and clinical relevance, the systematic topographical data on the architecture of the whole facial muscle system adds substantially to the sparse neurophysiological and anatomical knowledge at the level of the smallest functional units.

Longitudinal tracking of individual motor units using high-density surface electromyography

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BACKGROUND AND AIM: The possibility to identify the same motor units (MU) across multiple sessions of an experimental protocol may open new avenues in the neurophysiological investigation of motor neurons. However, this is not possible with classic recording techniques of intramuscular fine wire EMG. This recording method is indeed characterized by high selectivity, so that the waveform shapes of action potentials MUAPs of the same MUs are substantially different when the wires are inserted in the muscle multiple times. Therefore, in this study, we aimed to develop a methodology to track individual MUs using the combination of high-density surface EMG (HDEMG) recordings and convolutive blind source separation methods.

METHODS: We used two-dimensional arrays of 64 EMG electrodes to increase the spatial representation of the MUAPs. The recordings were performed from a decerebrated cat preparation as well as in healthy human volunteers. In the cat experiments, the MU tracking was attempted in the same experimental session, but on different trials with repositioning of the electrodes. The EMG signals were recorded on the gastrocnemius and soleus muscles. Due to the instability of the recordings, this type of experiment creates a considerable challenge for the MU tracking. In the human experiment, the signals were collected on 10 subjects in three days over different weeks. The MU were tracked along the three sessions. The participants were asked to perform two submaximal (10-70% of the maximal force) isometric knee extensions with HDEMG recordings placed on the vastus lateralis (VL) and medialis (VM) muscles. In both the cat and human experiments, blind source separation (Holobar et al., 2007; Negro et al., 2016) was applied to each individual recording for the identification of MU activity and the spatial signature of their MUAPs was used to track the same MU across trials. The spatial signatures were compared using 2D cross-correlation and normalized Euclidean distance. RESULTS: In the cat experiments, a total of 44 unique MUs was identified in all trials. Of these, 27 were tracked longitudinally across two trials, 16 across five trials, and 7 across nine trials. The tracked motor units showed a good consistency of peak-to-peak amplitude and conduction velocity estimates, with coefficient of variations of these variables <10%. Similarly, in the human experiment, the number of tracked MUs across two sessions varied (over the 10 subjects) between 21(6-34) and 23(6-40), while for three sessions it was possible to track between 11(8-17) and 11(1-16) MUs for VM and VL, respectively, across all force levels. CONCLUSIONS: The results demonstrates the possibility to track individual MUs longitudinally across trials performed in the same or different days using HDEMG, with repositioning of the electrodes. The methodology may be used to study the changes in the properties of individual MUs during intervention and progressive neuromuscular diseases.

Differences in motor unit discharge characteristics among proximal and distal muscles of the upper limb in individuals with chronic hemiparetic stroke

Laura Miller McPherson[1], Francesco Negro[2], Chris Thompson[3], CJ Heckman[4], Dario Farina[2], Jules Dewald[4]

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BACKGROUND AND AIM: Proximal and distal muscles serve different roles during functional tasks. In the upper limb, proximal muscles are typically used for postural control, and distal muscles are typically used for fine motor control. Differences in neural inputs to the muscles likely exist, but they have not been studied extensively. Analysis of motor unit (MU) discharge can help elucidate neural organization to a muscle in both the healthy and neurologically injured state. However, until recently, it has not been feasible to efficiently measure MU discharge in multiple muscles. Multi-channel surface EMG is a novel approach for extracting MU discharge that provides improved efficiency and automation. Using this approach in healthy controls (N=9) and those with chronic hemiparetic stroke (N=12, moderate-to-severe impairment), we examined the number of MU extracted (yield) and MU discharge characteristics (discharge rate, rate modulation, common drive) in proximal and distal arm muscles. METHODS: Participants were seated with the arm affixed to an isometric apparatus to measure shoulder, elbow, and finger joint torques. 64-channel EMG grids were placed on the surface of deltoid (DELT), biceps (BIC), and finger flexors (FF). Separate isometric contractions of shoulder abduction, elbow flexion, and finger flexion were performed at efforts ranging from 10 - 40% maximum torque. EMG data were decomposed into MU spike trains. Mean MU discharge rate (MDR) was calculated and compared against torque to estimate rate modulation. Coherence was calculated on composite spike trains and pooled across torque levels for each participant group. Z-transformed values for frequencies at 1-2 Hz were used to quantify common drive. RESULTS: Differences were found across muscles and/or groups for all metrics. Mean MU yield was highest at FF for both groups (Stroke: DELT: 5.6, BIC: 6.9, FF: 9.6; Control: DELT: 4.3, BIC: 3.8, FF: 12.0). For overall MDR, values were similar across muscles in controls (DELT: 13.7, BIC: 13.9, FF: 13.4 pps) but decreased from proximal to distal post-stroke (DELT: 11.4, BIC: 10.7, FF: 8.5 pps). Differences in rate modulation were also observed between groups. In controls, rate modulation was demonstrated by a positive relationship between MDR and torque in all muscles, and the slope between the variables increased from proximal to distal (DELT: 7.5, BIC: 16.6, FF 21.5 pps/%MVT). Post-stroke, however, rate modulation decreased from proximal to distal, and it was absent in FF (DELT: 7.9, BIC: 5.4, FF: -0.6 pps/%MVT). Common drive values were highest in FF for controls (DELT: 31.4, BIC: 30.4, FF: 51.6) but lowest for FF

in stroke (DELT: 63.8, BIC: 56.2, FF: 49.9). CONCLUSIONS: Results demonstrate differences in MU behavior among DELT, BIC, and FF and that the relationships between the muscles changes post-stroke. Findings underscore the need to record from multiple muscles when using MU analysis to examine neural organization to the upper limb.

How synaptic organization shapes the motoneuron to EMG transform

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The motor commands that produce EMG and movement comprise 3 components. Excitation and inhibition are of course fundamental. Yet motoneurons also have extremely potent neuromodulatory inputs via neurotransmitter systems that act on G-protein coupled receptors. This 3rd component of motor commands acts to control the excitability of motoneurons, i.e. their "state". Thus the response of a motoneuron to excitation or inhibition varies dramatically depending on its neuromodulatory state. There are multiple neuromodulators, but our emphasis is on serotonin (5HT) or norepinephrine (NE), which originate in the brainstem and are especially potent in their actions on motoneurons. By comparing our realistic computer simulations of these neuromodulatory actions to detailed surface array recordings of motor unit firing patterns, we are able to identify the relationship between the temporal pattern of EMG and the temporal pattern of all 3 components of motor commands. This identification is part of a systematic effort to reverse engineer the firing patterns of human motor units. Our result show a remarkable flexibility in the command to EMG transform, which has important implications for understanding to what degree EMG patterns reflect motor command patterns.

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S.16. ***Mobilizing Data: Research at the Intersection of Data Science and Biomechanics***

The Mobilize Center: accelerating movement science with big data

Jennifer L. Hicks[1] , Joy P. Ku[1] , Scott L. Delp[1,2]

[1]Departments of Bioengineering and [2] MechanicalEngineering, Stanford University

Mobility is essential for human health. Unfortunately, many conditions, including cerebral palsy, osteoarthritis, obesity, running injuries, and stroke, limit mobility at a great cost to public health and personal well-being. The proliferation of devices monitoring human activity, including mobile phones and an ever-growing array of wearable sensors, is generating unprecedented quantities of data describing human movement, behaviors, and health. Mobility data is also being collected daily by hundreds of clinical centers and research laboratories around the world. The mission of the Mobilize Center (mobilize.stanford.edu), one of 11 NIH Big Data to Knowledge (BD2K) Centers of Excellence, is to overcome the data science challenges facing this mobility big data to improve human movement across the wide range of conditions that limit mobility. In this talk we will provide an overview of the Center's research, training, and dissemination activities and share specific ways that the biomechanics community can participate in the Center.

Four Data Science Cores focus the Mobilize Center's data science research efforts. Our Biomechanical Modeling core is focused on developing robust, flexible, and automated optimization tools for generating personalized biomechanical models and simulations from diverse experimental movement data. Through our Statistical Learning Core, we are creating algorithms to make predictions and classifications and identify insightful correlations from large sets of noisy, sparse, and complex data, whether discrete or time-varying. The Behavioral and Social Modeling Core is focused on developing tools to model the role of behavioral and social dynamics in human health based on information collected with smartphones and wearable activity monitors. Finally, the Integrative Modeling Core is bringing the three approaches together to establish machine learning systems that integrate diverse

data sources and modeling approaches to aid clinical decision-making and transparently communicate with clinicians.

To ensure that our data science research has a significant impact on important health issues, we are focusing the activities of the center on three Driving Biomedical Problems. First, we are analyzing mobility data collected at Gillette Children's Specialty Healthcare to predict and improve the outcomes of surgeries in children with cerebral palsy and gait pathology. Second, we are integrating data from biomechanics labs and hospitals to identify new approaches to optimize mobility in individuals with osteoarthritis, running injuries, and other movement impairments. Third, we are analyzing wearable sensor data from millions of people to discover methods that motivate individuals to move more.

In addition to the research, the Center is also training scientists at the intersection of data science and biomechanics and sharing new tools with the data science and biomechanics communities. Our Massive Open Online Courses (MOOCs) train tens of thousands of students and researchers on topics such as Mining Massive Datasets, Statistical Learning, and Convex Optimization. We have established a Distinguished Postdoctoral Fellows and graduate student research program to create leaders in biomedical big data analytics. We also develop and disseminate general, open source tools for biomedical big data science including optimization, statistical learning, biomechanical modeling, and machine learning packages.

Stepping forward? Patient-specific measures of altered control to improve treatment outcomes in cerebral palsy

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Background: Improving movement after brain injury remains a formidable challenge, requiring new methods for enhancing rehabilitation and recovery. Every brain injury is unique and clinicians struggle to determine the optimal course of treatment for each individual. For example, cerebral palsy (CP) is caused by an injury to the brain at or near the time of birth and impairs movement and coordination. To improve movement, individuals with CP receive a wide variety of treatments such as orthopaedic surgery; however, only 50% of patients improve walking ability after various treatments. New methods are needed to optimize patient-specific treatment and improve quality of life. Aim: A long-held clinical belief is that variability in treatment outcomes is due to differences in motor control between individuals. However, no methods currently exist to quantify patient-specific changes in motor control. The goal of this research was to retrospectively evaluate whether motor control, measured by muscle synergies, was associated with treatment outcomes in CP. Methods: We analyzed 473 children with CP who had previously undergone treatment at Gillette Children's Specialty Healthcare and received pre- and postoperative gait analyses. Electromyography data from each gait analysis was processed using nonnegative matrix factorization to identify weighted groups of muscles consistently activated together (synergies). We defined the dynamic motor control index during walking (walk-DMC) as the variance accounted for by one synergy, scaled relative to synergies from 84 typically-developing (TD) children. Among the TD children, 100 is the average walk-DMC and 10 points is one standard deviation. Values less than 100 indicate a more simplified control, in which a single synergy describes more muscle coordination than in TD children. Stepwise linear regression models were computed, predicting changes in Gait Deviation Index (GDI), gait speed, and oxygen cost after treatment ($p < 0.05$ for variable entry, and $p > 0.10$ for variable removal). Results: The final regression models indicated that walk-DMC was correlated with post-operative GDI ($r2 = .42$) and gait speed ($r2 = .53$), but not oxygen costs. Thus, even after controlling for pre-operative GDI and speed, synergies provided a unique factor associated with improvements in gait. Individuals with a walk-DMC more similar to TD (closer to 100) were more likely to have improvements in gait after treatment. More aggressive treatments (orthopaedic surgery/rhizotomy) resulted in larger positive changes, but the effect size of treatment group was significantly smaller than walk-DMC effects. Conclusions: Muscle synergies were associated with treatment outcomes in CP and provided unique information beyond traditional gait analysis. These results confirm and provide a quantitative measure of clinicians' long-held belief that "motor control matters" for optimizing treatment in CP.

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Detecting foot strike from kinematics, a case study in the debate between hypothesis-first and data-first methods

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[1]University of Calgary

BACKGROUND AND AIM: Recently, technological advances have provided researchers with sophisticated data analysis procedures. These techniques afford new research opportunities, whereby large amounts of data can be explored for meaningful patterns. This approach, often referred to as data-driven or "data-first", contrasts sharply with a traditional hypothesis-driven or "hypothesis-first" approach. In turn, a debate has begun over the fundamental place of each of these approaches, in fields such as cancer genetics [1,2]. In human movement science, meaningful discussion is also timely in determining how we integrate these new techniques. Two recently published papers provide a case study which crystalizes this debate. The studies both address a common biomechanical problem, the detection of foot touchdown events from kinematics, along with two solutions: a hypothesis-first method, and a data-first approach. The aim of the current case study was to place these two approaches in the same problem context, and contrast them to provide insight into both. METHODS: Using a large database of running biomechanics, touchdowns were detected with: 1) a hypothesis-first method using peak downward velocity of the centre-of-mass [3], and 2) a data-first method based on angular accelerations at the foot, ankle, knee and hip, and using principal component analysis (PCA) -based machine learning [4]. Each method was then similarly applied to the detection of touchdowns for walking, which was a completely novel task for both. Performance in all cases was evaluated using gold-standard touchdowns from a rising-threshold of vertical ground reaction force exceeding 10 N. RESULTS: Both methods demonstrated very similar standard deviations of error in touchdown detections for running (hypothesis-first: 8.6 ms, data-first: 8.8 ms). However, attempts to extend the hypothesis-first method for walking demonstrated higher standard deviations of error (hypothesis-first: 20 ms, data-first: 8.3 ms). CONCLUSIONS: The hypothesis-first method relied on a narrowly-chosen sample, variable set, and movement task to produce results specifically applicable within those parameters. In contrast, the data-first method produced a generalized model that was independent of the specific sample and movement. This distinction is reflected in the view taken

when hypothesizing the outcome. In the hypothesis-first method, the authors created a fully-defined hypothesis, in which groups of subjects and variables of interest were pre-defined. In contrast, the data-first method utilized a general principle (Newtonian mechanics) to define a data boundary, within which variables of interest were thought to exist, but were not pre-defined. Other important contrasts are presented in Table 1. [1] R. Weinberg, Nature 464:678, 2010. [2] T. Golub, Nature 464:679, 2010. [3] C.E. Milner and M.R. Paquette, J Biomech 48:3502-5, 2015. [4] S.T. Osis, B.A. Hettinga, J. Leitch and R. Ferber, J Biomech 47:2786-9, 2014.

Characterizing Clinically Meaningful Phenotypes of Osteoarthritis Progression: Eight-Year Data from the Osteoarthritis Initiative

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BACKGROUND AND AIM: Osteoarthritis (OA) is one of few major chronic diseases that we still cannot treat. Stagnation in the development of robust preventative measures and disease-modifying treatments is partly due to poor characterization of the different types of osteoarthritis. Disease heterogeneity remains a confounder not only in the clinic, but also in the design of case-control studies that aim to advance our knowledge of disease progression. Diagnostic tools that predict clinically meaningful OA phenotypes are needed to facilitate the design and implementation of targeted and efficacious interventions. The leading aim of this study was to characterize distinct, clinically meaningful phenotypes of osteoarthritis progression. Secondarily, we sought to identify patient characteristics and short-term outcomes that are predictive of long-term progression. METHODS: We used publicly available data from the OA Initiative. To characterize progression phenotypes, we used joint space narrowing and pain progression on both knees, over eight years, for subjects who had or were at high risk of developing OA (n=2165). Each subject was represented by a vector of the changes in outcomes from baseline to each consecutive year, for both knees (ordered by most affected). A k-means clustering algorithm was used to identify distinct clusters of progression. Subject characteristics and outcomes for the first year were then used to predict the clusters. To identify the best predictive variables, we used least absolute shrinkage and selection operator logistic regression, with five-fold cross validation both for model selection and

validation, along with a bootstrapping approach for variable importance. RESULTS: A final number of three clusters was adopted after visual inspection to ensure that the clusters represented clinically meaningful paths of progression. The first cluster contained subjects who exhibited slow joint space narrowing and constant pain (typical phenotype); the second cluster contained subjects who had slow joint space narrowing and decreasing pain; the third included subjects with fast joint space narrowing and constant pain (Fig. 1). Accordingly, instead of one-versus all logistic regressions, we performed atypical phenotype vs. typical phenotype logistic regressions. Subject characteristics, such as demographics and comorbidities, predicted atypical progression phenotypes with over 60% accuracy. When change in joint space width and pain from baseline to the first year were included, predictive accuracy increased to over 80%. CONCLUSIONS: OA is increasingly recognized as a collection of diseases with a common clinical endpoint, but prevention, development of effective disease-modifying drugs, and optimal interventions are currently hindered by the agglomeration of patients into one category. The identification of clinically meaningful phenotypes of OA progression will enable faster progress towards treatment and prevention.

Data and data management for finite element analysis in joint biomechanics

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In biomechanics, finite element analysis provides a computational modeling and simulation platform to quantify the mechanics of the body, organs, joints, tissues, and cells in high level of detail. This modeling strategy enables the understanding of form-function relationships and also establishes the pathway through which loads of the higher spatial scales of joints and organs are reflected upon the mechanical environment of the tissues and their constituents. In this regard, finite element analysis provides the means to establish biomechanical markers for diagnostics and for evaluation of interventions, which have the potential to lead to individualized care. Like in any other simulation strategy, good models and reliable interpretation of predictions necessitate good input data. Finite element analysis is data rich. It requires representation of of anatomical properties, e.g., geometry of the knee and its tissue structures, representation of physiological properties, e.g., tissue material properties such as elastic modulus of cartilage, and prescription of loads and boundary conditions acting on the structures of interest, e.g., forces applied to the knee. In return, simulations can predict the response of the system (for the case of the knee, tissue stresses and strains, and joint movement), a rich output set that needs further mining for appropriate scientific and clinical interpretation. Ideally, if input data are personalized, predictions can be specific to the individual, an important aspect of individualized medicine. Towards that direction, many data challenges in finite element analysis need to be resolved. These challenges are at various levels throughout the lifecycle of the model; among many are the availability of data, acquisition of missing data; merging of existing data to approximate missing data, documentation and organization of raw and derivative data and simulation results, dissemination and re-use of data, models and simulation results. The goals of this study were i) to provide an overview of data needs for finite element analysis, with specific attention to joint biomechanics, and ii) to describe data management strategies for effective modeling promoting reproducibility and reusability. The Open Knee(s) project was used as an example. This activity aims for the development of completely specimen-specific (anatomically and mechanically) models of knee joints as a virtual knee population. The project acquires and blends heterogeneous data sets - imaging, joint mechanical testing, tissue testing, with ongoing documentation and prompt dissemination. This project is funded by the National Institute of General Medical Sciences, National Institutes of Health (1R01GM104139 - Principal Investigator: Ahmet Erdemir).

Moving Forward: From Physical Activity Monitoring to Physical Performance Monitoring

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BACKGROUND AND AIM: Mobility impairment is a key feature of osteoarthritis (OA) and lumbar spinal stenosis (LSS), yet efforts aimed at this are hampered by the lack of an objective measure. Here, physical activity monitoring seems a logical solution. Surprisingly, accelerometer-based studies in these populations reveal few, if any deficits relative to controls. The identification of objective and quantifiable measures of function would improve disease classification, evaluation and treatment. The goal of this study is to apply recently developed accelerometry measures along with novel analytics in populations with OA and LSS. We aimed to use these methods to 1) identify characteristic movement patterns (physical performance "PP" phenotypes) that are unique to individuals with OA and LSS, and 2) determine optimal methods to differentiate between the conditions. METHODS: We previously uncovered novel accelerometry signals of regional-body pain from a population-based sample, and empirically derived thresholds for accelerometry analysis tuned to the impact of musculoskeletal pain (called the physical performance "PP" analysis). In this study, we interrogate 3 datasets: the Osteoarthritis Initiative (OAI), the National Health and Nutrition Examination Survey (NHANES), and the Lumbar Spinal Stenosis Accelerometry Database (LSSAD). To characterize the unique accelerometry signals in all 3 groups, we tested the existing Freedson intervals for movement frequency and novel features of movement from the PP analysis. We then evaluated the significance of each feature alone in discriminating (pairwise) between groups. Finally, we determined which set of features best classifies individuals between groups (the PP phenotypes). RESULTS: All features were significant at $p<.05$ after accounting for multiple hypothesis testing, except for the following intervals: Freedson moderate, Freedson vigorous. Also, Freedson vigorous was not significant between LSSAD and OAI, nor was PP moderate-vigorous between LSSAD and NHANES. The PP phenotype classification rates for OA and LSS demonstrated roughly 80% accuracy (pairwise) relative to the pain-free population, given age and gender. The most important distinguishing features corresponded to sedentary and light activity. The subtler classification between diseased populations (OA vs. LSS) was at 72%, with moderate activity as the prominent distinguishing feature. CONCLUSIONS: We show it is possible to derive new insights from accelerometry data by developing a novel set of features that characterize the movement patterns of OA and LSS (called "physical performance" phenotypes). These features were found to be statistically significant in discriminating between populations. Furthermore, our approach determines a key set of discriminatory features, resulting in a framework for classifying musculoskeletal diseases, and provides a comprehensive quantitative analysis of real-life physical performance.

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S.17. *Practical Application of Electrophysiology and Kinesiology*

Application of multi-channel surface EMG technique to researches of aging and lifestyle-related diseases

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In Japan, aged members of the population (> 65 ys old) made up 25.1% in 2105, and this percentage is the highest in the world. We should note that Japanese people spend, on average, 9 years of their life receiving nursing care. Also, number of lifestyle-related disease patients, such as those with type 2 diabetes mellitus (T2DM), recently markedly increased in Asia-Pacific countries including Japan. For the prevention and management of age-related physical dysfunctions and lifestyle-related diseases, exercise for improving muscle strength and/or muscle hypertrophy has been strongly recommended. However, physiological responses of the neuromuscular system in the elderly and lifestyle-related disease patients during exercise have not been fully elucidated. Here we introduce our recent research applying multi-channel surface electromyography (SEMG) to investigate the effect of aging and lifestyle-related diseases on neuromuscular functions. We recorded multi-channel SEMG from the vastus lateralis muscle of the elderly and T2DM patients using a two-dimensional grid of 64 electrodes. Spatial distribution SEMG patterns and decomposed individual motor unit action potentials, analyzed by the Convolution Kernel Compensation technique (Holobar et al. Clin Neurophysiol 2009) were assessed to investigate motor unit recruitment and firing patterns (Watanabe et al. J Electromyogr Kinesiol 2012; Diabetes Res Clin Pract 2012; Muscle nerve 2013). Our results suggest that motor unit recruitment/firing strategies are modified in the elderly and T2DM patients during force production. We also investigated mechanisms of age-related dysfunction in locomotion using a multi-channel SEMG. During the swing phase of the gait, in the rectus femoris (RF) muscle, the proximal region is selectively activated (Watanabe et al. J Biomech 2014). This phenomenon can be explained by region-specific functional roles within a muscle, i.e., proximal regions of the RF muscle mainly contribute to hip flexion, while all regions of this muscle contribute to knee extension (Watanabe et al. J Electromyogr Kinesiol 2012).

In the elderly, this regional activation during the swing phase was attenuated (Watanabe et al. J Biomech 2015). We suggest that region-specific functional roles within a muscle may be a key to age-related dysfunction in locomotion. The knowledges derived from multi-channel SEMG proves new insights into how the neuromuscular function is altered due to aging and lifestyle-related diseases, and may help to establish effective exercise programs for the elderly and patients with such diseases.

Rehabilitation robot using muscle activity and neural decoding

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BACKGROUND AND AIM: Non-invasive measurement method, such as EEG, fMRI or NIRS, has been used for brain-machine interface (BMI). EEG has nice temporal resolution, and it is often used for BMI. Recently, electrocorticography (ECoG) is used as an alternative approach to less invasive BMIs. Since ECoG records directly from neuronal activities on the cortical surface, ECoG has higher spatio-temporal resolution with better signal-to-noise ratio than scalp EEG. Several studies using ECoG have already succeeded in the classification of movement direction, grasp type, and prediction of hand trajectory. Despite these successes, however, there still remains considerable work for the realization of ECoG-based prosthesis. Additionally, recent studies using electromyography (EMG) have suggested that many muscles in a human body are controlled by combination of fewer activation patterns, called muscle synergies. It is also known that motor impairments following neuronal damages are related to partial changes of the muscle synergies. METHODS: The human neuromuscular system naturally modulates mechanical stiffness and viscosity to achieve proper interaction with the environment. Current rehabilitation robots can perform sophisticated operations including stiffness control. Our model is constructed with the musculo-skeletal model which can predict the angle, torque, and stiffness of joints from muscle activity. Our BMI system decode muscle activity and estimate the motion using musculo-skeletal model. RESULTS: We introduce our researches on estimating mechanical properties of musculo-skeletal system from EMG signals, and its application to robot control (Shin et al., 2009; Kawase et al.,

2012). Then we introduce BMI using muscle activity decoded from EEG and ECoG recordings (Yoshimura et al., 2012; Shin et al., 2012; Nakanishi et al., 2013; Chen et al., 2014). Finally, we introduce our recent results of muscle synergy analysis in patients with hemiparesis, and its potential application to rehabilitation robots using muscle activity. CONCLUSIONS: Decoding muscle activity is an important component for realizing BMI systems capable of controlling interaction force or stiffness. Understanding the relationship between the synergies and motor impairments may enhance possibilities of robot-aided rehabilitation using measured or decoded muscle activity. ACKNOWLEDGEMENT: A part of this study was the result of "Brain Machine Interface Development" carried out under the Strategic Research Program for Brain Sciences by MEXT/AMED. This work was supported in part by Grant-in-Aid for Scientific Research on Innovative Areas (26112004) from MEXT.

Ubiquitous approach for health and sport

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Now Japan is super aged society, and the ratio of senior citizen for the population will reach a peak in 2025. It is important to the society that a senior citizen lives healthy. The need of their health care increases to live a healthy life. It is important to measure biological information every day and to predict a change of the health condition from the tendency. We received the support of Ministry of Education, Culture, Sports, Science and Technology since 2011 and started the research of the unconscious biomedical measurement in the daily life. The purpose of this study is to develop the system to measure the biomedical information during daily life, to analyze them and to transfer the results to a medical institution. The developed system enabled an unconscious measurement of a heart rate, blood pressure, exercise and the body temperature. For heart rate measurement, we developed two system. One was a photoplethysmography using green light. This is not affected by the motion artifact. The other was the system using electrocardiogram which was led non-contactly from a sheet on a bed. We developed a chair for cuffless real-time estimation of systolic blood pressure based on pulse transit time. Furthermore, using an unconscious exercise monitoring system, we developed the remote instruction system for the rehabilitation at home. The noninvasive wearable deep body thermometer was also developed. This thermometer is helpful for a person having difficulty in body temperature adjustment.

A Remote and Non-Contact Monitoring System of Physiological Indices to Cope with Visually Induced Motion Sickness

Makoto Yoshizawa[1], Norihiro Sugita[1], Makoto Abe[2], Akira Tanaka[3], Noriyasu Homma[1], Tomoyuki Yambe[1]

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[Background] Head mounted displays or three dimensional wide screen television sets are frequently used for not only video games but also virtual reality rehabilitation. However, these displays sometimes cause visually induced motion sickness (VIMS). To cope with VIMS, it is important to quantify the degree of VIMS by extracting physiological indices from viewers. Physiological indices can be obtained from electrocardiograms, blood pressure, pulse waves (sphygmograms), galvanic skin responses, and so on. However, contact-type sensors are required to measure these parameters. On the other hand, it has been reported that pulse waves can be obtained in a non-contact and remote fashion by processing video signals taken by usual video cameras. In addition, it is possible to take information on blood flow or blood pressure at once because video signals are related to two dimensional information on blood volume under the skin. [Objectives] The purpose of the present study is to develop a remote and non-contact monitoring system for extracting physiological indices from viewers watching a video display to cope with VIMS. [Methods] Hemoglobin included in blood well absorbs the green components of ambient light, and thus the green video signal reflected from the human skin has information on blood volume under the skin. By using this fact, the pulse waves can be obtained to extract physiological indices as follows: 1) The region of interest on the video image is tracked by using face recognition or skin color identification and divided into plural small segments. 2) Mean brightness intensity of green components over each small segment is calculated and memorized as a time series. 3) Band-pass filtering with the pass-band of 0.5-2Hz with FFT and inverse FFT is applied to each time series data to remain only heart beat components. 4) The phase difference in mean intensity between proximal and distal areas from the heart is

calculated, and then the pulse wave transit time is obtained from the phase difference. [Results] A laptop personal computer with a front camera was used to operate the monitoring system developed with C++ and OpenCV. Fig.1 shows a snapshot of the movie image (20fps) of the monitoring system. In Fig.1a), mosaic images corresponding to intensity of the video pulse are superimposed on the subjectýfs face image. Fig.1b) shows pulse waves before and after filtering, and Fig.1c) shows heart rate. The phase difference was obtained as the difference time between the local maxima and minima of time series corresponding to two areas shown in Fig.1a). [Discussion and Conclusion] On the basis of the video pulse signals obtained above, several physiological indices such as the ratios of LF/HF of heart rate and the pulse amplitude, and so on will be estimated. However, the video pulse wave includes more noises than that measured with contact-type photo sensors and the frame rate should be higher to take more accurate phase difference information

Brain-muscle-machine interface: controlling a prosthetic hand

Ryu Kato[1]

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To develop brain-muscle-machine interfaces, many Japanese researchers have proposed methods to approximate fine hand movements using electromyograms and cranial nerve signals. The applications toward realizing electric prosthetic hands are particularly remarkable. Our group has developed a multi-DOF myoelectric hand using three myoelectric sensors, which can produce eleven types of hand-finger movements (YK-Hand), enabling people who have lost their forearm to regain their freedom in daily living. This presentation introduces the current state of myoelectric hands in Japan, our multi-DOF myoelectric hand (YK-Hand), and other methods to estimate hand movements based on adaptive learning of individual differences and time-variances in myoelectric features. There are two types of YK-Hands: the multi-DOF and the practical/simple type. The former uses a wire-driven robot hand to approximate the biarticular muscle structure of a human hand, while the latter uses a two direct-drive actuator capable of three basic movements (grasping, tripod pinching, and lateral pinching). The adaptive learning method to estimate hand motions consist two components: motion-discrimination unit and on-line learning unit. The motion-discrimination unit discriminates classes of various hand motions

using myoelectric frequency characteristics and a neural network. The on-line learning unit learns/modifies training data for motion discrimination based on the continuity of the discrimination results and an information entropy representing the similarity of myoelectric features of different classes of movements. A high discrimination rate (> 85%) is possible for eleven types of hand movements, even after nine hours of continuous prosthetic hand use. To investigate how users become proficient and adapt to a myoelectric hand, we measured the brain activity of a user during continuous use by fMRI and evaluated the changes in brain activity. Our results show that the primary motor and sensory cortex are activated concomitant with proficiency of prosthetic hand use. Additionally, for a user to stably control various types of hand motions, much muscle strength must be exerted. Consequently, a prosthetic hand may feel unnatural and cause physical fatigue. To combat these issues and help users have a more natural experience, we propose a new control method for a myoelectric hand using a hand-motion discrimination method based on electromyograms during pre-shaping movements and a grip speed control method using estimates of object-based attention from electric signals originating in the eye. Our method reduces the muscle activity to one-third the previous value. Moreover, the control grip can control the grip speed, which can be decreased by increased focus on an object by the user (e.g., when gripping a small object). By controlling the approach movement prior to gripping on object, we achieved a more stable and closer approximation to natural hand movements.

S.18. ***Intermittent control***

Intermittent Control provides a deterministic explanation of linear and remnant components of human stance control without injection of random noise.

Cornelis van de Kamp[1], Henrik Gollee[2], Peter J Gawthrop[3], Ian D Loram[4]

[1]Delft University of Technology, [2]University of Glasgow, [3]University of Melbourne, [4]Manchester Metropolitan University

BACKGROUND AND AIM: Traditional models on human stance control explain our irregular sway pattern by injecting random (sensor and/or motor) noise acting, closed-loop, on a continuously operating circuit. Here we present a deterministic explanation that, as a consequence of intermittent event triggered decision making, reproduces the non-linear remnant and the linear frequency response as well as a continuous controller with added noise. METHODS: Data in the context of controlling a human-in-the-loop system was collected in 9 participants who were strapped to a single segmental inverted pendulum structure pivoting around the ankle joint. Stance control of the human-attached-to-pendulum system was achieved by feeding a control signal derived from EMG signals measured at the Tibialis Anterior and calf muscles to the virtual unstable inertial second-order system whose output (sway movement) was transmitted via a very strong actuator to the controlled system. Participants used all available sensory feedback to reject a multi sine input disturbance under three levels of disturbance amplitude (small, medium, large) applied to the system. Our method of analysis consisted of two stages. In the first stage, we fitted linear time-invariant control parameters to the excited frequency response (CC). In the second stage, to provide a benchmark, we improved the fitted power at all frequencies by adding noise derived by calculation of the non-linear remnant (CCn) and, to test the intermittent control explanation (IC), we adjusted four parameters of the intermittent controller (Sampling Delay, Event Thresholds on position, velocity and force states) . RESULTS: Our results show that, unsurprisingly, the continuous model fits the experimental power at all frequencies when a customised noise spectrum for each disturbance amplitude level was added. The key finding is that also the Intermittent Controller fitted the observed variability using a physical model without additional noise. At the high disturbance amplitude level, the distribution of Open Loop Intervals shows small values. At the low disturbance amplitude level, we found substantial Open Loop Intervals (of more than 1 second). CONCLUSIONS: Our findings indicate that when disturbances are low, and sway is predictable, continuous sensory feedback is not required. The key conclusion is that intermittent use of sensory information using thresholds on state prediction errors can explain human stance control as well as a traditional linear model with added noise.

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Intermittent control: a general paradigm for understanding sensorimotor control

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BACKGROUND AND AIM: Human motor control is constructed through central processes of selection and reinforcement learning. Our ability to investigate mechanisms is linked to the tools available. The collection of control principles, theoretical models, system identification methodologies, behavioural and neural data collectively forms a paradigm within with investigation occurs. METHODS: Continuous feedback provides the predominant paradigm for sensorimotor control. Within the continuous control paradigm discrete decision making is restricted typically to an undeclared, higher process which passes optimised control parameters to a lower continuous regulatory loop. The continuous regulatory loop models the fast, reflexive spinal, brainstem and trans-cortical responses that have been studied extensively physiologists. The intermittent rather than continuous use of sensory information to update control signals implies an event trigger determining when to use sensory information, a discrete sampling/initialisation process and a hold process constructing a time varying control trajectory (Figure 1). The effect of the open loop interval is to reduce the control bandwidth. The benefit is (i) the event related possibility to iteratively reinitialise the control basis and (ii) the availability of predictively stabilised open loop time to provide state dependent optimisation. In short, intermittent v. continuous control trades online flexibility for control bandwidth. Recent theoretical and methodological advances have provided new behavioural evidence of sequential, refractory response selection during sustained sensorimotor control. While including continuous control as a special case omitting the discrete sampling and hold processes (green blocks in Figure 1), intermittent control provides a more general paradigm in which discrete refractory selection occurs as a serial, sequential, single channel process within the main feedback loop. RESULTS: Intermittent control has been considered, increasingly extensively, as a paradigm for studying motor control, adaptation and learning in man and in robotics applications. Distinguishing intermittent from continuous control is confounded by the masquerading property of intermittent control. With experience, human control is smooth even if it is constructed sequentially. While continuous control is well established for studying reflexive sensorimotor control, when motor decision making, learning and adaptation are considered, intermittent control becomes more relevant. This talk introduces the symposium to show how the intermittent control paradigm is becoming increasingly established and plausible from all aspects - control theory, principles, system identification methodology, behavioural data and neural substrates. CONCLUSIONS: This paradigm has value for basic science, for interfacing humans with machine devices, for informing diagnosis of sensorimotor impairments and for informing rehabilitation.

A machine learning model of intermittent control

Ryan Cunningham[1], Ian Loram[1]

[1]Manchester Metropolitan University

BACKGROUND AND AIM: There is considerable evidence that the human central nervous system uses intermittent control to control movement. If this were the case, one can hypothesise that intermittent control is necessary; therefore one might ask why does the CNS need intermittent control? The current consensus is that the human brain needs 'thinking time' to couple motor actions with state representations when decisions and actions are sufficiently complex. We present a novel machine learning framework for studying intermittency in the human brain. METHODS: State feedback is fed into a state representation, which is fed into a complex, interconnected layer of neurons (proposed) called intermittent long short-term memory (iLSTM). Based on LSTM, these neurons can store sensory information for many time steps, which can be used to influence the rest of the system; in contrast to LSTM they predict the state input one continuous time step ahead. iLSTM neurons are controlled by gated (black circles) connections; node d switches between state information a or a model prediction of the state c by excitatory (blue), and inhibitory (red) connections. The state input has a self-recurrent connection, gated by a reset node h which controls the proportion of a that is retained over time. The main input node g is controlled by a gated connection to f, which controls the proportion of g which is written to a. The coloured connections are fixed, while the black connections are adaptive, and can be learned using back-propagation through time, given a desired state and a state error. The state (predicted/measured) is fed into the rest of the network, then into an action representation, which encodes the actual control signal. The many recurrent connections are analogous to the 'thinking time' believed to be a possible reason behind intermittent control. The system can block access to sensory data, and use a model prediction, then cycle many times through the network, to produce the appropriate control response. Symbols within the nodes indicate linear and nonlinear. RESULTS: Our approach gives investigators the ability to model control systems without explicitly designing delay parameters, intermittent intervals, or indeed whether open loop or closed loop control would provide the best solution to a given problem. Our approach also provides a framework for investigating intermittency in control systems, with respect to whether intermittency is required, and if so, which situations it is required for and why. By learning only from a state representation and a desired state, the network can learn optimal parameters on node d controlling the output gate. Our hypothesis is that if intermittent feedback is necessary for a given system, then the network will learn to use sensory input intermittently, and only for learned intermittent intervals. CONCLUSIONS: We present our on-going investigations using this framework to identify systems hypothesised to be intermittent.

Remnant response in visual-manual tasks and intermittent control

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BACKGROUND AND AIM: Variability, together with non-linearity, are fundamental features of human movement. They are associated with the response component which is not linearly related to the input, i.e. the remnant response. The conventional explanation attributes the main source of remnant to stochastic noise imposed on a continuously operating feedback loop, and the resulting variability is usually regarded as a nuisance. We explore an additional explanation in which the remnant response is an inherent mechanistic feature arising from an event-driven intermittent control loop. We present a two stage frequency domain approach which is used to identify, from experimental data, a continuous controller with added suitably coloured sensory noise, or, alternatively, an event-driven intermittent controller. METHODS: We considered a manual control task to balance an unstable system with dynamics similar to an upright human, where 11 participants were given visual

feedback to follow different control priorities, while the control signal is disturbed by an external multi-sine periodic disturbance with components at discrete frequencies. In stage 1 of our identification procedure (see figure), a linear continuous control model (CC) was fitted to the periodic component by averaging the complex frequency response over all periods. In the 2nd stage, the analysis period was extended, allowing us to differentiate between the responses at non-excited frequencies (the remnant) and at excited frequencies (which include the linear, periodic response and a remnant component). The remnant was modelled by either adding suitably coloured sensory noise (based on the response at non-excited frequencies) to the continuous controller (CC+noise), or by using an event-driven intermittent controller (IC), based on the CC design from stage 1, with appropriately optimised threshold parameters. using a cost function which includes the PSD at excited and non-excited frequencies to ensures that the total power of the response is fitted. Simulated data from these two explanation were also used to explore whether our approach could differentiate between a CC or IC explanation. RESULTS: The CC+noise can explain the experimental data well, but the added noise spectra are highly dependent on the experimental instructions. The IC can explain the frequency responses equally well, but only requires the adjustment of the parameters of the intermittent event detector. The values of these thresholds are related to the instructions, e.g. precise position control is associated with small thresholds, whereas relaxed instructions result in larger thresholds. CONCLUSIONS: An identification approach has been developed which demonstrates that event-driven IC can reliably fit the remnant spectrum of manual-visual control, suggesting that purely mechanistic features of the controller may play an important role as a source of variability in human movement.

Sensorimotor dynamics in the brain during intermittent control of goal-directed movements

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BACKGROUND AND AIM: Regulation of limb position in response to intermittent disturbances has been shown to occur over short and long timescales. FMRI studies indicate overlapping brain networks contribute to sensorimotor corrections over

these time scales, but the temporal dynamics mediating intermittent corrections remain unclear. We examined cortical network dynamics associated with intermittent closed-loop control and impairments that arise when feedback timing is disrupted. METHODS: We used 64-channel EEG to probe temporal dynamics of error correction in cortical networks. Healthy people (N=7) used a 1-D wrist robot to perform pursuit tracking of a moving visual target. Subjects generated intermittent corrections to performance errors induced by forces applied to the wrist (proprioceptive "P trials") or visual displacements of the cursor (visual "V trials"). Distributed source modeling identified cortical contributions to average EEG activity. We used the same setup to examine how demyelination and delays in feedback (esp. visual) in multiple sclerosis (MS) contribute to sensorimotor impairment. Sixteen subjects (8 with MS and tremor; 8 controls) regulated cursor position relative to a stationary visual target in response to band-limited visual or torque perturbations to the cursor or arm. RESULTS: In P trials, current source maps reveal early somatosensory, premotor, motor, and frontal activity ranging from 43±5 ms to 48±6 ms post-perturbation, followed by parietal activity at 70±8 ms. In V trials, parietal activity (113±8 ms) was followed by sensory, motor/premotor activity (123±42 ms to 131±22 ms). This reflects differential processing of proprioceptive and visually perceived errors. In the absence of visual feedback, errors are first computed in (and acted upon by) premotor/motor areas before a parietal estimate of error is available. When visual feedback is present, performance errors are first computed in parietal regions before being processed in motor areas. In MS subjects, we postulated that submovement intervals (derived from velocity profiles) correspond to an internal prediction of feedback delay. Consistent with this, V trial submovement intervals and response delays did not differ for control subjects ($t(9)<1.4$, $p>0.05$). By contrast, MS subjects with moderate to severe tremor (4 of 8) had V trial response delays much greater than controls ($t(7)=2.55$, $p=0.038$). In P trials, where feedback delays are much shorter, submovement intervals and response delays did not differ across groups ($t(9)<1.6$, $p>0.05$). CONCLUSION: These studies suggest that intermittent control is mediated by short and long feedback loops utilizing overlapping brain areas with different temporal dynamics. Altered timing of feedback through these networks leads to mismatches between predicted and actual delays, resulting in motor impairment. Future studies will explore how intermittent control is synchronized across the senses to maintain closed-loop stability.

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A dual Kalman filter approach to adaptation in intermittent control

Jose Alvarez Martin[1], Henrik Gollee[1], Ian Loram[2], Peter Gawthrop[3]

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BACKGROUND AND AIM: Intermittent Control (IC) has been used to describe the modular architecture that underlies human motor control. Recent studies on human motion indicate that the parallel flow of sensory information converges to a serial ballistic process which includes the planning and selection of desired motor responses, suggesting that such a process is beneficial when complex optimization or flexible adaptation is needed to compute optimal motor output. These ideas allow us to hypothesize that adjusting our control actions to compensate for changes in the system that is being controlled could be modelled by incorporating adaptation strategies into this framework, which exploit the advantages of having open-loop intervals punctuated by instances of intermittent feedback. By designing an adaptive, self-tuning, intermittent controller based on Kalman filtering estimation principles, this study aimed to examine the effects of using adaptation techniques on a postural balance model and the possible extensions to other engineering systems. METHODS: The concept of a self-tuning regulator provides the foundations for our adaptive intermittent controller. First, an estimate of the time-varying parameters of the system is obtained in order to redesign the controller at a later step. The estimation procedure, for both, states and parameters, is performed by a dual Kalman filter that runs continuously. The estimated parameters are only used to update the control law when an event is triggered by an error exceeding a predefined threshold, using optimal control techniques. In other words, sensory information is updated continuously, but only used when needed to adjust the control strategy. The open-loop interval serves as an ideal time frame to estimate the changes in the system. This intermittent moving time-horizon allows slow optimization procedures to take place simultaneously with fast control actions, increasing the computational time for adaptation. The fact that during the open-loop period, the controller uses a predefined control trajectory (computed at every feedback instant), provides time to run online identification procedures without this representing a heavy computational burden. RESULTS: This controller was applied to a dynamical model of human balance, and compared to a corresponding continuous controller (CC). Fig. 1 shows the estimates obtained by both controllers when one of the parameters changes suddenly. When IC is used, the estimate converges to the real parameter at a faster pace, reaching 80% of the value in less than 0.1s compared to up to 0.3s for the CC. The CC approach updates the control law at every sample whereas IC only does it when an event is triggered. CONCLUSIONS: Our results suggest that the proposed methodology is a good candidate to model online adaptation processes within the IC framework, providing a flexible algorithm that could potentially be used to reproduce human behaviour.

Intermittency using boundary control

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BACKGROUND AND AIM: Many research studies have attempted to approximate how people move using optimal control modeling approaches. However, more functional tasks tend to have flexibility of movement choice, rendering optimal solutions arbitrary. For example, there are a variety of ways one might catch an incoming object. An alternative method of action planning would be to simply avoid adverse situations, allowing all other forms of activity to be possible. Such control approaches open up new possibilities and also allows intermittency in the controller. METHODS: Our demonstration experiment required subjects to intercept objects anywhere along their trajectory. We also added robotic limit-push forces that pushed the hand further away once it exited an invisible region. RESULTS: With practice, subjects distributed their actions more uniformly within these boundaries. We will show that control variables such as distance- and time-to-edge of these boundaries increase with practice, supporting the notion that the nervous system attends carefully to their control. A simple computational model demonstrated that such a controller can intermittently turn its attention to other matters for a few moments. CONCLUSIONS: We speculate on the general idea that all other formulations of control might be instances of this type of control. This concept of "avoiding bad" makes it possible to easily execute intermittent control in complex activities, and also can be used to explain the wide variance of actions seen in some behavior.

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Day 1, WEDNESDAY JULY 6

P1-A-1 Bilateral and unilateral training does not affect classification accuracy for prosthesis control

Usha Kuruganti[1], Victoria Chester[1], Ashirbad Pradhan[2]
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BACKGROUND AND AIM: Most powered transradial prostheses use the amplitudes of surface electromyography (EMG) signals from the forearm flexors and extensors to control the opening and closing of the hand. Users must co-contract their forearm muscles as a switch to rotate the wrist. This operation can be slow and is not intuitive, as the user is required to use the same muscle contractions to control different functions. Pattern recognition based controllers perform movements based on EMG patterns, rather than using individual EMG from the residual muscle. Therapists use a series of movements to train prosthesis users to successfully operate their devices with the assumption that the intact limb is considered the dominant side while the affected limb (whether by congenital or traumatic occurrence) becomes the nondominant side. The purpose of this work was to examine upper limb movements to determine 1) if there is any decrement to pattern classification accuracy due to the type of movement (bilateral versus unilateral) and 2) if limb dominance affects pattern classification accuracy. Understanding the impact of these movements may help to improve training protocols for upper limb prosthesis users. METHODS: Ten able-bodied males (mean age = 31.6 ± 12.0 years) participated in this study. A high-density (HD) EMG system (REFA, TMS International) was used to evaluate four different hand movements (?hand open,? ?hand closed,? ?pronation,? and ?supination?) at a self-selected medium contraction level. Participants were asked to complete the movements in two conditions, bilateral (both hands together) and unilateral (one hand at a time). Participants were asked to indicate their dominant limb. Surface electrodes (n=32) were placed over the forearm to collect HDEMG data. Pattern classification accuracies were computed for all movements using an LDA pattern classifier. RESULTS: The mean classification accuracies for each movement and condition are shown in Table 1. Analysis of Variance indicated that there was no statistically significant difference in classification accuracy due to condition (bilateral vs. unilateral) or limb dominance. CONCLUSION: The results suggest that high pattern classification accuracy can be achieved and that there is little to no impact due to the type of movement completed, whether it is with one hand or two. In addition, limb dominance did not affect classification accuracy. This suggests that therapists may not be limited to specific actions for user training.

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P1-A-2 Assessment of muscular fatigue and force by double normalized surface electromyography spectrum - proof of concept

Robert Seibt[1], Monika Rieger[1], Benjamin Steinhilber[1]
[1]University Hospital Tübingen

A new model was developed to assess muscular force and fatigue by surface electromyography measurements. This model includes a double normalization of the frequency-amplitude-spectrum (FAS) from the SEMG. It allows discriminating between simultaneously changing force and fatigue levels and is based on the fact that force and fatigue induce different but predictable pattern in the changing FAS. An individual baseline FAS and several normalization measurements allow to estimate transform functions for fatigue and force in relation to the mentioned baseline FAS. These "normalizing" or "convolution" functions enable estimating the magnitude of applied muscular force and the level of fatigue by the FAS of an occupational task. Simplifying these functions to normalized amplitude relations in selected frequency bands is also possible if larger errors are acceptable. Here, a proof of concept of this model will be provided for isometric muscle contraction of two muscles of the shoulder-arm region. Method: In one experiment (exp A) 15 subjects performed isometric muscle contractions at the lower arm and in another experiment (exp B) 10 subjects performed isometric muscle contractions at the shoulder. These contractions included different force levels related to the force measured under maximal voluntary contraction (MVC) and were different in duration in order to induce defined force and fatigue levels which were controlled by a force sensor. Bipolar SEMG was recorded continuously and transformed to the time domain using Fourier Transformation. In exp A the SEMG of extensor digitorum muscle was recorded. Subjects performed a MVC, short contractions at 20% and 40% MVC as well as a fatiguing contraction until task failure (30% MVC). In exp B SEMG of the trapezius muscle was applied. The subjects performed a MVC, short contractions at 20% and 50% MVC as well as fatiguing contractions until task failure (20% and 40% MVC). In both experiments the FASs of time intervals from the SEMG curves were determined. These time intervals included SEMG curves from the unfatigued muscle at different force levels as well as SEMG curves from the exhausted muscle with a substantial amount of muscle fatigue. To proof the concept the values of the known muscular forces and fatiguing levels were compared to the values estimated by SEMG analysis. Results: So far, about 40% of the data were analyzed. The preliminary results show a very good accordance between applied force and muscular force assessed with the new method (double spectrum normalization) particularly at low and mid fatigue levels. Muscular fatigue could be estimated semi-quantitative e.g. described by "non-low-medium-high fatigue". Our results further indicate that this applies to different force levels. Further investigations will be done in order to proof the model.

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P1-A-3 Concentric and eccentric muscle activation of patients with knee osteoarthritis during dynamic contractions - A categorized and probabilistic analysis.

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BACKGROUND: In patients with osteoarthritis (OA) deficits on muscle activation are attributed to the weakness and imbalance of the muscles around the knee. From healthy subjects it is known that during dynamic contraction joint position, movement velocity and contraction type affect significantly the activation of different muscles by the central nervous system. However, its impact during dynamic activation is still doubtful in patients with knee OA and becomes a challenge due to their complex and uncertain characteristics. AIM: The aim of the study was to determine the effect of joint angle position and movement velocity on concentric and eccentric activity of knee muscles of patients with OA and to compare the results with the muscle activation of age matched healthy subjects. METHODS: In twenty-seven women, sixteen with knee OA (age 64 years (SD=5.7); weight 69.6 kg (10.3); height 1.63 m (0.08 m)) and eleven controls (age 65 years (4.4); weight kg 61.1 kg (8.0); height 1.54 m (0.08 m)) volunteered to participate in this study. Surface electromyography (sEMG) of knee extensor and flexor muscles were recorded during twenty-five extension and flexion movements performed on an isokinetic dynamometer in three different velocities (90, 120 and 240 º/s). Three joint angle intervals of approximately 15° steps were determined between 30º to 70º. Initially, for patients and healthy subjects the data were categorized into groups of constant velocity, activation type (eccentric or concentric) and joint angle interval. For each categorized group the cumulative frequency distributions of the normalized sEMG envelopes were computed for each muscle separately. From the frequency distributions, the probability has been calculated that in OA patients normalized sEMG envelope values could be higher or lower than in controls. RESULTS: During extension movements, patients with OA are more likely to show higher EMG activity of the eccentric working of BF and ST muscles regardless of the joint position and velocity. Concentric working muscles VM, VL and RF are more likely to show lower activation than controls, especially in the more extended positions of the knee. During flexion movements, patients with knee OA are more likely to show higher activity of the eccentric working of the VL muscle without taking into account the joint position and the movement velocity. CONCLUSION: The difference in muscular activation strategy of OA patients compared to controls depends on the contraction type (eccentric or concentric), regardless the joint position and the movement velocity. Based on this knowledge improved new strength and balance exercises may be designed and the potential for intervention and prevention might be improved

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P1-A-4 EMG-force relationship of the lower posterior neck during isometric contractions

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BACKGROUND AND AIM: In order to provide basis for improved accuracy of current biomechanical neck models, this study examined the relationship between surface electromyographic (EMG) activity and isometric force of the posterior neck. METHODS: Nine males and nine females in the age of 20 to 48 years conducted isometric neck extensions in a neutral spine posture against a fixed force transducer. Seven muscle contractions were reiterated in a random order at 5-90% of maximal voluntary force. EMG activity was registered bilaterally from the cervical erector spine at C7 level, and processed with a zero phase band-pass filter at 20-400 Hz; and both EMG and force data was smoothed with a one second moving average. An automated script was utilized to identify the most stable second within 5% of target force together with the coinciding EMG activity. The neck torque was calculated and adjusted for gravitational acceleration, and EMG and force data were normalized as the percentage of maximal reference activity. To improve data stability, normalized EMG data was averaged between neck sides. Linear mixed-effects models regression was used to predict EMG from force and the most parsimonious model was selected as the final model. To assess absolute model fit, the coefficient of determination (R2) and the root mean square error (RMSE) were used. RESULTS: Figure 1 shows lowess curves for the observed data (black) and for the fitted model (red). A positively oriented quadratic curve had the best fit. Marginal and conditional R2 values were 0.93 and 0.98, respectively, and RMSE was less than 4%; both indices supporting a good model fit. CONCLUSIONS: These results suggest that the lower posterior neck's EMG-force relationship over nearly the full range of voluntary maximal activity is curvilinear, and that the slope is steeper for higher intensities.

P1-A-5 A method for evaluation of dependency between diseased side and opposite side of hemiplegia patient during FES-Cycling by using transfer entropy

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BACKGROAUND AND AIMS: Functional electrical stimulation (FES) is an effective method of rehabilitation for patients have paralyzed limbs caused by brain disease. FES can promote functional recovery because the stimulation produces contraction in paralyzed muscle and

joint movement. In particular, for patients with hemiplegia, cycling with FES by using an ergometer is widely executed. Although the performance of cycling is usually evaluated using the crank angular velocity, pedaling force, and so on, it is difficult to evaluate the recovery level for hemiplegia by these indexes. Because the diseased side is assisted by healthy side, the performance of during cycling is averaged. It can be evaluated whether the diseased side contributes to cycling motion by using the electromyogram (EMG). However EMG cannot be measured under FES. It is necessary to evaluate muscle activities under FES without electrical methods. Therefore, objective of this paper is to find indexes that can evaluate the difference of performance between the diseased side and the healthy side during FES-Cycling. METHODS: We adopted the Ultrasonography for measuring muscle activities. For verification, we measured EMGs simultaneously. Moreover, EMG, the crank angular, and the pedaling force also measured. We measured the healthy subject, and applied a load to his one leg to imitate the hemiplegia. Muscle activities achieved by ultrasonography are quantified by using image processing., and compared with EMG. Moreover, we verified whether it is possible to evaluate the difference of performance between hemiplegia legs by using transfer entropy. Transfer entropy is a quantity that can evaluate the dependency between two measured data of differ phenomena each other. RESULT: From the transitions of EMG and muscle activities, it is found that the interval which demonstrated muscle force of the loaded leg is delayed. Because the loaded side is assisted by opposite side, the velocity of muscle contraction according to applied load is varied. These facts should be confirmed by not only performance measuring. The transfer entropy between EMG of each quadriceps is varied depend on the condition whether one leg is loaded or not. Moreover, there is a correlation between the transitions of EMG and muscle activities. CONCLUSION: In this paper, we constructed the system that evaluates the performance and muscle activity during FES-Cycling. For the result, we found the following three points; (1) the difference of performance between hemiplegia legs is revealed by observing the transition of EMG and muscle activities, (2) the transfer entropy between each quadriceps is varied depend on the condition whether one leg is loaded or not, and (3) the feature quantity related to the condition of load on one leg is obtained by using ultrasonography. From the above, in case that EMG cannot be measured, for example during FES, ultrasonography substitute for EMG to evaluate muscle performance.

P1-A-7 Decomposition of Clinically-Detected EMG Signals Using Dynamic Time Warping and Spectral Clustering

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AIM: A system capable of decomposing clinically-detected electromyographic (EMG) signals is described. The system is specifically tailored to extract information for the characterization of neuromuscular disorders. The design philosophy behind the proposed system is conservative but reasonably effective. It is conservative in that it does not try to assign every segmented motor unit potential (MUP), nor identify every component MUP train (MUPT). Instead, the focus is to identify a subset of MUPTs that can be used to investigate disease induced changes in MUP shape and the stability of MUP shape across a train. The proposed methods are specifically tailored to accommodate issues that are particularly relevant to the analysis of clinically-detected EMG signals in the context of characterizing neuromuscular disorders. These issues include: (1) random within-train MUP shape variability due to neuromuscular transmission variability and (2) trending within-train MUP shape changes mainly caused by slow and slight electrode movement. METHODS: Segmenting MUPs from a composite filtered EMG signal starts by estimating the characteristics of the baseline activity. This is followed by finding peaks and evaluating the shape of isolated MUPs. Each of the potentially isolated segmented MUPs is set to be a node in a similarity graph. The edges of the graph are added based on morphological similarity as evaluated using dynamic time warping (DTW). A spectral analysis of the similarity graph is then utilized to perform clustering. RESULTS: The methods were validated and evaluated using simulated signals obtained from an electro-physiologically sound model. The results confirm the representativeness of the identified MUPTs. Those MUPTs, who's MUPs have an amplitude-to-noise ratio that is five or above, mostly contain MUPs comprised mainly of contributions from the same motor unit (99% ± 5.8%). The average processing time for ten seconds of EMG signal is 4.7 ± 0.38 seconds. CONCLUSION: The main advantage of using spectral clustering for MUPT identification is that it is a graph based clustering approach that finds clusters optimizing the connectivity among MUP shapes rather than their compactness. This is important to track MUPTs with slowly varying characteristics due to slow electrode movement. The main reason for using DTW alignment is to calculate a distance that is least affected by within-train MUP shape variability resulting from neuromuscular transmission variability.

P1-A-8 Different responses of fingertip forces and muscle activity of the enslaved finger during dynamic tasks

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BACKGROUND AND AIM: Fingers of the human hand cannot move or exert force independently, a phenomenon that is called enslaving. Anatomical research has indicated many cross-connections between muscle bellies of the long finger flexors (Frohse & Frankel, 1908), of which the mechanical effect is as yet uncertain. Enslaving might have a mechanical course, but alternatively involuntary co-activation of multiple muscle heads may be responsible. Investigating finger interaction during dynamic tasks can provide more insight into the relative contribution of neuromuscular control and mechanics. The aim of the current study was to investigate finger force enslaving during index finger flexion and to assess the relationship with activity patters of several extrinsic muscle regions. METHODS: Eleven right-handed subjects (22-30 years) were asked to flex the index finger from 0 deg. to approximately 45 deg. in 1.35 seconds while overcoming a 6N constant resistance force orthogonal to the finger tip. This force was produced by a robotic arm following the index finger while the other fingers (middle, ring and little) were resting against a board. Forces exerted by the restricted fingers were measured using unidirectional force sensors. Forces exerted by the index finger were measured by the robotic arm. Activity of muscles was measured using surface electromyography electrodes (sEMG). 24 electrodes were placed on flexor digitorum superficial (FDS) and extensor digitorum (ED) muscle regions. Each subject performed the task 4 times. RESULTS: Flexion force applied by the non-instructed middle finger increased substantially (by 1.91 N ± 0.79) during flexion of the index finger. Force exertion on the middle finger started to increase (defined by a threshold of 5%) with a delay of 108 ± 94. In contrast to the finger forces, the activity of the middle finger FDS region (FDS III) changed only minimally (by 4.8 % of EMGmax) upon flexion of the index finger. Therefore, any delay could not be accurately detected. The change in EMG activity of FDS III was not significantly correlated to the change in middle finger force (R= 0.26 p=0.15). Change in the activity of the middle finger ED region (ED III) was 1.8 % of EMGmax; Also for ED III no accurate delay could be computed. CONCLUSIONS:Our results indicate that the response to index finger flexion of fingertip forces in the non-instructed middle finger was different to that of FDS III and ED III activity. This mismatch between forces and EMG suggests that mechanical connections between muscle-tendon structures were likely to be responsible for the observed finger enslaving. The delay in the development of middle finger force may be explained by intertendinous connections initially being slack and pulled tout by index finger flexion. In addition, force transmission between muscle bellies corresponding to index and middle fingers may play a role.

P1-A-9 Effect of yoga on balance, lumbopelvic stability and back muscles power in women

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Effect of yoga on balance, lumbopelvic stability and back muscles power in women Professor Areerat Suputtitada ,M.D. 1,2,3 , Associate Professor Sompol Saguanrungsirikul,M.D.,2,3,4,

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Kittikorn Singhabut ,PT, MsC 2,3 1 Department of Rehabilitation Medicine, Faculty of Medicine, Chulalongkorn Universitry, Bangkok, Thailand 2 Excellent Center for gait and Motion, King Chulalongkorn Memorial Hospital, Bangkok, Thailand 3 Sport Medicine, Faculty of Medicine, Chulalongkorn University,Bangkok, Thailand 4Department of Physiology, Faculty of Medicine , Chulalongkorn Universitry, Bangkok, Thailand Abstract Background: Yoga is considered to be popular exercise especially for women. There are few studies of effect of yoga on motor performance. The aim of this study was to reveal the motor performance of yoga exercise. Methods: Randomized, single blinded controlled study was done. The effect of 6-week yoga exercise, 30 minutes per day for twice a week, was studied in healthy middle aged women. Thirty-nine women, aged between 30-45 years old, were randomized into yoga and control group. Before and after 6 weeks, participants were measured postural sway by using force plate during double and single leg stance while eyes opened and closed, lumbopelvic stability by angular displacement and angular velocity during single-leg landing, Gluteus medius and back muscles activities by surface EMG and muscle power by using isokinetic dynamometer. Results: We found that balance in single-leg stand in yoga group were significantly greater than control group ($p<0.05$). There was no significant difference between groups for angular displacement and angular excursion. The angular velocity showed significant difference between groups for mean velocity of lateral bend ($p<0.05$). EMG activities of gluteus medius muscles and back muscles power in yoga group revealed decrement than control, but no statistically significant difference. Conclusion: Therefore 6-week yoga exercise , 30 minutes per day for twice a week, totally 12 days, can improve balance, back muscles power and lumbopelvic stability. These might decrease risk for low back pain and fall risk in women. Keywords: Yoga, Balance, Lumbopelvic stability, Back muscle power

P1-A-10 Dynamic Curve Analysis of Surface EMG Patterns of Abdominal Muscle as a Function of Exercise and Load

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BACKGROUND AND AIM: Human movement variability has been conceptualized as a complex adaptive system that can be evaluated across multiple levels. The time-dependent structure of human movement and physiological signals provides insight into the state of the neuromuscular system with a wide range of analytical approaches used to characterize the complexity of signals. However, limited study of electromyography (EMG) complexity has occurred in healthy individuals which is needed to determine effective rehabilitation approaches. METHODS: The present study examined surface EMG (sEMG) activity from the rectus abdominus muscles during two exercises (traditional sit-up and reverse crunch). There exercise were performed in bodyweight (BW) and loaded (4.54 kg) conditions and with a fixed pacing (60 bpm). Dynamic curves of sEMG were computed over five consecutive movements for root mean square (RMS) and approximate entropy (ApEn). Comparisons of the dependent variables were made for mean values during concentric and eccentric phases. Additionally, the collective dynamic curves for RMS and ApEn were inspected to characterize dynamic changes during the concentric and eccentric phases as a function of exercise and load. RESULTS: Mean RMS showed non-significant differences during both concentric and eccentric phases for the main effects of exercise and load. The mean ApEn value of the sit-up was significantly higher than the reverse crunch for the concentric phase ($p<0.01$) but similar during the eccentric phase ($p=0.15$). No effect of load was observed for ApEn in either phase. The RMS curves reveal the envelope of sEMG with distinct transitions between concentric and eccentric phases. Characteristic drops in ApEn preceded the initiation of sEMG activity but primarily occurred during the concentric, but not eccentric, phase. CONCLUSION: In clinical and rehabilitation settings EMG has been widely used to evaluate and assess various neurological conditions but little is know about the time-dependent properties of muscular activity. The reported findings contribute to our understanding of the nonlinear dynamic properties of sEMG and highlight the need to examine the complexity of sEMG to aid in the ability to distinguish between healthy individuals and neurological disorders.

P1-A-11 Use of high density EMG grid recordings to characterize the level of injury in individuals sustaining cervical spinal cord injury

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BACKGROUND AND AIM: Ability to control limbs and muscles after spinal cord injury (SCI) depends on the severity and level of injury. Currently, the SCI level assessment is based on a combination of clinical tests (manual muscle testing: MMT) and medical imaging (MRI). There is an imperfect correlation between them. As a first step in establishing the functional level of motor injury, we here report the feasibility of using high-density surface EMG grid (HDsEMG) to characterize muscle regions innervated by damaged ventral roots. METHODS: In an ongoing study, we recorded a surface EMG 16x8 grid; IED=8.5mm (2KHz; monopolar; isometric non-fatiguing contractions) from Biceps Brachii (BB) in chronic SCI individuals (n=2; C5-C6 with ASIA C and C5-C7 with ASIA D). Subjects were examined in a sitting position, 120° elbow flexion, 30° shoulder flexion and 35° abduction with 45° pronated wrist. EMG data and elbow flexion force were recorded at rest, during maximum voluntary contraction (MVC) and at sublevels (20%, 40%, 60%MVC). The recorded EMGs were preprocessed by a low pass filter (10-500Hz; Zero lag; 4th order Butterworth) and powerline interference was removed using the spectral interpolation. We localized the innervation zones (IZ) along

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columns of the EMG grid by visual inspection of single differential EMG signals on both arms. In addition, the EMG signals were segmented in time using 125ms epochs and root mean squared (RMS) maps were calculated in all epochs. The active regions in the resulting RMS maps were extracted using the watershed segmentation, and frequency of each channel appearing in the active region was counted. RESULTS: Both participants were injured at cervical levels from C5 to C7 where musculocutaneous nerve originates and innervate both the BB and Brachialis. Injuries at these levels affect elbow flexion and extension. The left and right arm's IZ maps were different in terms of number and distribution of IZs. We observed multiple IZs distributed up to 25mm apart along the BB's fascicles on the less functional arm, which provides evidence of successive de/re-innervations. The recorded difference between left and right BBs highlights the sensitivity of the proposed technique in estimating the SCI extent. We did not see any spasms during recordings, but active motor units (MU) were observed through analyzing EMG signals at rest. Using the HDsEMG and watershed segmentation we quantified the active EMG channels and localized the active MUs in the resting state. The analysis of RMS maps at sub-levels of the MVC revealed the location of newly recruited MUs in response to the descending commands in response to the required forces. CONCLUSIONS: Our preliminary data is promising and established the feasibility of HDsEMG technique in characterizing, quantifying and tracking the extent and level of SCI. The proposed technique potentially complements the clinical examinations such as MRI and MMT and provides a functional map of injury.

P1-A-12 Reliability of muscle fiber conduction velocity and fractal dimension of surface EMG during isometric contractions

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BACKGROUND AND AIM: During isometric constant-force contractions, muscle fiber conduction velocity (CV) decreases, whereas the level of motor unit synchronization, by the central nervous system increases. Therefore, the evaluation of peripheral aspects of fatigue might be obtained by estimating CV rate of change during an isometric task. As regards central components of muscle fatigue, fractal dimension (FD) is considered a promising sEMG with a high sensitivity to motor unit synchronization. The aim of this study was to determine the test-retest reliability of CV and FD rates of change obtained from multichannel surface electromyographic (sEMG) recordings. METHODS: 40 healthy subjects (20 men and 20 women) performed two elbow flexions, on two sessions with a 1-week interval. The first was a 20% maximal voluntary contraction (MVC) of 120 s, and the second at 60% MVC held until exhaustion. sEMG signals were detected from the biceps brachii using a bidimensional

array of 64 electrodes. CV and FD were estimated on single differential signals, using non-overlapping signal epochs of 1s. Rates of change of CV and FD were used for the reliability analysis. RESULTS: The intraclass correlation coefficient (ICC) values for the isometric contraction at 20% MVC were 0.67 (95% CI: 0.49 - 0.79) and -0.09 (95% CI: -0.72 - -0.31) for FD and CV respectively. The ICC values for the isometric contraction at 60% MVC were 0.82 (95% CI: 0.73 - 0.89) and 0.78 (95% CI: 0.65-0.86) for FD and CV respectively. The Bland Altman plots for the two isometric contractions showed a mean difference close to zero: at 20% MVC 0.00153 for FD and -0.0277 for CV, and at 60% MVC 0.00666 for FD and 0.00907 for CV. CONCLUSIONS: The results suggest that during an isometric fatiguing contraction, CV and FD rates of change, are reliable variables, with potential application to evaluate peripheral and central contributions to muscle fatigue.

P1-B-13 A comparison of knee joint kinematics and kinetics during landings in three one-leg hop tests (hop for distance, vertical hop and side hop) performed by female elite floorball athletes.

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BACKGROUND AND AIM: Anterior cruciate ligament (ACL) injury is very common in sports, with an increased risk for females [1]. They mainly occur in non-contact situations with multi-plane knee loadings, often involving an eccentric movement. Common one-leg tests conducted before returning to sports include the hop for distance (OLH), the vertical hop (VH), and the side hop (SH). More knowledge is needed regarding the demands these tests put on the knee joint for improved evaluation and rehabilitation of knee function before returning to full sports participation. The aim was to study differences in knee joint landing kinematics and kinetics during these three hops for healthy elite female floorball players. METHODS: Ten female elite floorball players (Age: 21.4 ± 2.6 yrs., BMI: 22.2 ± 2.5 kg/m2) with no known injuries participated. Knee joint angles and moments in sagittal, frontal, and transverse planes were recorded using an eight-camera motion capture system (Oqus, Qualisys AB, 240 Hz) and one force plate (Kistler, 240 Hz) during landings from three one-leg hop tasks: OLH, VH, and SH. The SH was standardized to a lateral hop distance of 25÷body height with a rebound hop back to the start position. The landing phase was defined from ground reaction force >10 N to the first local minimum point on the ground reaction force curve. Knee moments were normalized to height and body mass. Repeated-measures ANOVAs followed by Bonferroni post-hoc tests were performed. RESULTS: Knee joint angles and moment magnitudes were generally greatest for the OLH test. Subjects had greater maximal knee flexion angle ($p<0.001$), adduction angle ($p=0.001$), flexion moment ($p=0.001$), and external rotation moment ($p<0.001$) during OLH than both VH and SH. Subjects had however greater abduction angle (p=0.004), internal rotation moment (p=0.012) and abduction moment (p=0.005), but lower adduction moment (p=0.001), in SH compared to OLH. During SH compared to VH, subjects had greater abduction moment (p=0.024) and internal rotation moment (p=0.017), although lower adduction moment (p<0.001) for the SH. CONCLUSIONS: Elite female floorball players showed significantly different movement patterns in landing between the three different hop tests. The OLH had greater demands on flexion, adduction, and external rotation, while the SH had greater demands on internal rotation and abduction. This indicates that each of these tests provide valuable information of knee function demands but in different movement directions, something that is important to consider in the rehabilitation after a knee injury. KEYWORDS: Movement patterns, biomechanics, kinesiology, knee function, anterior cruciate ligament [1] Myklebust et al., A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. Scand J Med Sci Sports, 1998. 8(3): p. 149-153.

P1-B-14 The Kinematic Chain Ratio of Pronation-to-Supination of the Calcaneus and Internal-to-External Rotation of the Shank Affects Calcaneus Motion during Gait

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BACKGROUND AND AIM: The kinematic chain of pronation-to-supination of the calcaneus and internal-to-external rotation of the shank in the standing position provides smooth movement, such as gait, because the kinematic chain has a conversion function between movements of the foot and shank on the plane of motion. Therefore, it appears that the effects of individual differences in the ratio of the movement of both segments have a significant influence on lower limb movements during gait that cannot be ignored because there is a large individual variation in the ratio. This study clarified the relationship between the kinematic chain of the calcaneus and shank and lower limb movement during gait. METHODS: Forty limbs of 20 healthy adults (13 males and 7 females; age, 26.3±3.9 years) without a history of orthopedic disease in the lower extremities were studied. Using a 3D motion analysis system (VICON-NEXUS; Vicon Motion Systems, Ltd., Oxford, UK) and force plates (AMTI, MA, USA), the kinematic chain movement, such as pronation/supination movement of the calcaneus and rotational movement of the shank in the standing position, and lower limb movement during gait were measured. We defined the linear regression coefficient between the calcaneus and shank angles during standing as the kinematic chain ratio (KCR, shank angle-to-calcaneus angle) in the kinematic chain movement. The relationship between the KCR and angles of the calcaneus and shank during standing was analyzed using Pearson's correlation coefficient (significance at p<0.05). RESULTS: The mean of the KCR was 1.0±0.2. The mean of the range of movement of pronation/supination of the calcaneus was 10.4±2.3 degrees, and the internal/external rotation of the shank was 18.7±4.4 degrees during gait. The correlation coefficients between the KCR and the range of calcaneus and shank movement were r=-0.69 (p<0.001) and r=-0.38, respectively. CONCLUSIONS: We previously described large shank rotation, namely a large KCR in the high arch alignment of the foot (The 50th Congress of the JPTA). Furthermore, a high arch foot has a small movement of the calcaneus during running because the foot has high rigidity (Nawoczenski, 1998). We suggest that such a relationship is the basis for a relatively strong negative correlation between the KCR and the range of calcaneus movement during gait. Although the KCR and the calcaneus movement are factors to increase the shank rotation, the correlation coeffecitnt between the KCR and the shank rotation was not significant. This phenomina was caused by various KCR among subjects to keep the shank rotation in medium range. From the above, if the deviant state from the results of this study, namely if the KCR and the calcaneus movement are large, there will be a possibility that the shank rotation is occurring in excess. When analyzing lower limb motion during gait, it should be noted that there is a large individual variation in the KCR.

P1-B-15 Effects of Non-local Fatigue on EMG Amplitude During Dynamic Resistance Exercise

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BACKGROND AND AIM: The physiological mechanisms responsible for the manifestation of non-local fatigue during resistance exercise are not well established. Alternating upper- and lower-body exercises provides for time-efficient workouts, but can impair external work of the lower-body, when compared to lower-body only resistance exercise. The purpose of this study was to determine how added upper-body resistance exercise affects lower-body muscle activation. METHODS: Four resistance-trained males (20.8±2.9 yrs; 79.38±8.75 kg) completed two workouts on two separate days. One workout (lower body: LB) consisted of two warm-up hip sled sets followed by three hip sled sets to failure at 90% of one-repetition-maximum (1RM). Another workout (whole body: WB) consisted of two warm-up sets of hip sled and lat pull-down exercises followed by three sets of 90% 1RM hip sled sets to failure with 80% 1RM lat pull-down sets performed to failure between the three 90% hip sled sets. Subjects received instantaneous visual feedback to perform repetitions at a rate of 2 seconds for eccentric and concentric movements. Bipolar electrodes sampled surface electromyographic EMG signals at 1000 Hz from vastus lateralis, vastus medialis, and rectus femoris muscles. EMG amplitude was expressed as percent of average EMG root mean square (rms) during the first warm-up set. Custom LabVIEW software was used to process

the data. Alpha was set at .05. RESULTS: A 2 (workout) by 3 (set) ANOVA found there to be no significant main effect of workout condition on number of completed repetitions (p=.367; η=.273); there was a significant main effect for set (p=.014; η=.862) reflecting fewer successful completed repetitions in later sets; there were no significant interactions. A 2 (workout) by 3 (set) by 3 (muscle) ANOVA indicated no significant main effect of workout condition on mean EMG rms (η=.516; 95% CI LB=203.01-246.41%; 95% CI WB=158.45-248.25%). However, there was a significant main effect for workout (p=.014; η=.898) where WB (4.83% increase per repetition) had a lower slope than LB (7.00% increase per repetition). There were no significant interaction effects for EMG rms. CONCLUSION: Performing upper-body resistance exercise between lower-body resistance exercise sets may result in lower intra-set increases in EMG amplitude. This may be explained by lower-body muscles maintaining higher metabolite concentrations during lower-body "rest" intervals due to increased circulating metabolite concentrations.

P1-B-16 Electromyographic analysis of the soleus and vastus lateralis muscles during squat exercise with and without isometric contraction in the end of eccentric phase

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BACKGROUND AND AIM The squat is a free weight exercise used to maximize the strength of the lower limbs, contributing to a better athletic performance. Surface electromyography (EMG) and creatine kinase (CK) are used as indicators of muscle fatigue enabling process understanding of neuromuscular behavior for training methods of athletes. The aim was identify the behavior of EMG and CK variables in two protocols that differ by the additional isometric contraction phase during the squat exercise. METHODS Five subjects (23,5 ± 2,79 y.o., 78,47 ± 9,12 kg, 174,4 ± 6,22 m) with 2,5 ± 3,2 years of experience give their written consent to participate the study. One-repetition maximum test (RM) was performed 72 hours before for each of the two protocol and it was observed a rest (without training) of 10 days between them. Protocol 1 (P1) without isometric contraction phase at 70% of RM and Protocol 2 (P2) with isometric contraction phase (2s) in the end of the eccentric contraction phase at 70% of RM. Both protocols were with 5 series and 12 repetitions. The EMG signals of soleus and vastus lateralis muscles were acquired during the P1 and P2. It was adopted the 1s window length for the 1st contraction (first), 8th contraction (middle) and 16th contraction (last) of each series (1º, 2º, 3º, 4º and 5º). The feature median frequency (MF) was used for statistical tests (Two-way ANOVA - p=.05). Creatine Kinase (CK - U/L) was collected at 72h before, 24h and 48h after protocols (statistical tests - Multivariate repeated measures analysis - p=.05). RESULTS Few differences in the EMG signal were observed in the protocols (P1 and P2) and in the series for both muscles (Fig. 1). It was not expect differences for the soleus muscle (postural) among contractions over the protocols, while the vastus lateralis muscle (with a predominance of fast fibers) had change in the frequency of the EMG signal due to the occurrence of muscle fatigue generated in the protocol. For the CK values it was observed that the CK after 24 hours for P1 (769.6 ± 681.45 U/L) showed a significant increase of 31%, approximately (p = 0.02) when compared to P2 (530, 8 ± 518.47 U/L), with the highest concentration to P1 (p = 0.01), indicating the occurrence of muscle damage. There were no significant differences between groups for the before 72 hours CK (P1 = 419.4 ± 270.4 and P2 = 345.6 ± 225.9 U/L) and in CK after 48 hours (P1 = 524.8 ± 441 and P2 = 318.14 ± 407 U/L). The MF feature is considered a frequency indicator of recruitment of motor units, however, it was not sensitive to the occurrence of muscle damage indicated by CK during dynamic and isometric contraction. CONCLUSIONS Considering the inclusion of isometric contraction (P2) was the only difference between protocols and that only the value of CK 24 hours after had statistical differences, the EMG MF feature was not sensitive to measure this type of squat exercise protocol.

P1-B-17 Muscle fatigue in vibration exercise at different frequencies

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BACKGROUND AND AIM: Because of enhanced neuromuscular demand, Vibration Exercise (VE) has been suggested to improve muscle strength and power performance. However, the use of optimal VE protocols in rehabilitation programs is still lacking due to poor understanding of the underlying physiological mechanisms. In this study, the fatiguing effect of vibration at different frequencies was investigated by employing a force-modulation VE system. This system, described in [1], applies to the muscle a baseline force (tension) that can be modulated at different frequencies. METHODS: 15 volunteers performed four 12-s isometric contractions of the biceps brachii. The load consisted of a baseline force of 80% of the maximum voluntary contraction (MVC) with 60% sinusoidal force modulation at 0 (control condition, no vibration), 20, 30, and 40 Hz, in randomized order. The EMG was measured by a 64-channel high-density grid with a Refa8 multichannel amplifier (TMSi, Netherlands). Mechanical fatigue was estimated by assessment of the MVC decay. The MVC was measured before and after each task with a load cell embedded in the system. Myoelectric fatigue was estimated by analysis of the EMG signals recorded during VE. The time-evolution slope of the EMG conduction velocity, mean-frequency, power (RMS), and fractal dimension were considered as indicators of myoelectric fatigue [2-3]. The latter was considered as a possible indicator of central fatigue [3]. All the myoelectric indicators were

estimated with and without Vibration-Frequency Removal (VFR) from the EMG, as these frequency components can derive from either motion artifacts or muscle activity [4]. RESULTS: All the results are shown in Fig. 1. Normalization to the maximum value was performed for each subject. These results suggest VE, especially at 30 Hz, to produce a larger degree of fatigue as compared to control condition. DISCUSSION AND CONCLUSIONS: Statistical significance was achieved for all fatigue indicators with exception for the fractal dimension, suggesting VE to enhance peripheral fatigue as compared to central fatigue. Further analysis of VE central fatigue is required by dedicated measurements. In general, these results motivate towards the introduction of VE in rehabilitation with improved training programs. REFERENCES: [1] L. Xu et al, 'Novel vibration-exercise instrument with dedicated adaptive filtering for electromyographic investigation of neuromuscular activation,' IEEE T-NSRE, 21(2):275-282, 2013. [2] R. Merletti et al, 'Myoelectric manifestations of fatigue in voluntary and electrically elicited contractions,' J Appl Physiol, 69(5):1810-20, 1990. [3] L. Mesin et al, 'A bi-dimensional index for the selective assessment of myoelectric manifestations of peripheral and central muscle fatigue,' J Electromyogr Kinesiol, 19(5):851-863, 2009. [4] L. Xu et al, 'On the nature of the electromyographic signals recorded during vibration exercise,' Eur J Appl Physiol, 115:1095-1106, 2015.

P1-B-18 Effects of Neuromuscular Training for Runners with Flexible Flatfoot and Related Running Injuries

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Background and Aim: Biomechanical stresses in subjects with flexible flatfoot (FFF) during running and other loaded activities with high repetition easily cause significant injuries to the musculoskeletal system. Excessive rearfoot pronation would cause increased lower extremity internal rotation and pelvic anterior tilt, and could also lead to excessive knee valgus, hip adduction, and pelvic instability in dynamic movements. These abnormal skeletal malalignment causes poor force transfer between the foot and spine in functional movements and accumulated tissue stresses in the lower extremity and lumbar region over time, leading to the development of lower extremity injuries such as patellofemoral pain syndrome, shin splints, plantar fasciitis and low back pain. To offset the malalignment associated with FFF, it is important to re-establish the kinetic control and maintain joint stability from the foot to spine and integrate them into functional activities of daily living. However, no studies have investigated the effects of neuromuscular control exercise on lower extremity kinetic control and symptom improvements; especially in runners with FFF. The purpose of the study was to investigate whether neuromuscular training from the foot to spine is beneficial in runners with FFF and lower extremity pain. Methods: This study was a

one-group pretest-posttest quasi-experimental design. We recruited 17 runners with FFF and running related lower extremity pain and provided them with neuromuscular training from the foot to spine. Outcome was evaluated by visual analog scale (VAS) for pain and lower extremity functional scale (LEFS), as well as lower extremity kinematic and electromyographic changes after 6 weeks of training. Results: There was no significant difference on the kinematics data, but muscle activation of tibialis anterior and biceps femoris was significantly higher during both functional tasks, and activation of peroneus longus was lower during level walking in symptomatic runners with FFF. After 6-week neuromuscular training, runners with FFF showed significantly smaller hip adduction and trend of decreased hip internal rotation during single leg squatting. In muscle activity, tibialis anterior were lower during level walking and higher during single leg squatting. These subjects also reported decreased pain and increased lower extremity function after 6-week training. Conclusion: Neuromuscular training was benefical to lower extremity motor control and improved pain and dysfunction in runners with FFF.

P1-B-19 Does longer application of kinisiotape delay the muscle fatigue of the knee joint during isotonic flexion/extension?

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INTRODUCTION: Kinesiology tapes (KT) claim to improve biomechanical performance of users through a delay of muscle fatigue. There is a controversy from previous studies that researched short-term performance of these claims in both healthy and injured subjects [1-4]. A number of studies demonstrated some improvement in active range of motion of the knee joint & reduction in pain in subjects with knee injuries [1,2], while other studies shown little to no improvements in strength in healthy subjects [3,4]. The aim of this pilot study is to investigate whether the longer term application of KT improves performance of the healthy knee joint and delays the muscle time to fatigue (TTF). METHODS: Four healthy male subjects (ages 20-25, height 72.2±2.0in, weight 168.7±22.5lbs) with no previous history of knee injuries volunteered to participate. A commercially available KT was applied to the dominant knee per manufacturer's guidelines. A 7-day isotonic fatigue protocol, with a resistance of 60lbs, was conducted in 24hr increments from prior to KT application (nKT) to 6-days of KT application (D1-D6) using a Biodex 4 Pro dynamometer. EMG's of the Vastus Lateralis (VL) and Medialis (VM) were collected unilaterally at 2kHz, and band pass filtered at 20-450Hz using DelSys Trignio surface EMG sensors. The RMS of muscle activity was calculated and normalized to a 3sec standing baseline of its corresponding day. The percent change across each day was calculated for RMS and MDF with KT and was compared to nKT. TTF was determined from the time the subject starts to when they can no longer perform knee

extension/flexion and rate was calculated as number of cycles per second. RESULTS: No change was seen at the time immediately after KT application in any of the parameters. An increase in RMS and a decrease in MDF from start to end of each trial, indicating fatigue, was seen in all subjects. Overall greater drops in MDF were seen at nKT with an average of 27.9% and 18.6% for the RVL and RVM respectively. Continuous delays in TTF were seen throughout all days of KT application. A maximum delay of 85% in TTF was reached at D4 and then it gradually started to decline. Slight increases (up to 13%) in average rate of knee extension and flexion were seen across all subjects. Therefore, the delays in TTF cannot be due to slow down in rate, and may indicate a potential advantage of KT. SUMMARY: It was found that the duration of KT application can be an important factor and one could expect some endurance enhancement in knee extensors after 24hrs of KT application. Larger studies and additional applications are needed to explore the pathophysiology of these findings.
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P1-B-20 Shoulder problems in elite adolescent handball players - the Karolinska handball study

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BACKGROUND AND AIM: Shoulder pain and overuse injuries in the shoulders are common in both female and male elite team handball players. Recent studies have showed a 25-33% season-prevalence of shoulder pain among senior elite players, and 12% of male elite players reports substantial shoulder problems. The amplitude of shoulder problems and risk factors for developing shoulder injuries among elite adolescent team handball players are unknown. The overall objective with the on-going cohort study called Karolinska Handball Study is to deepen the knowledge about injuries prevention and the functional status in the neck/shoulder area in adolescent elite handball players. The specific aim of this part project is to describe the prevalence of shoulder injuries in the included elite adolescent handball players. METHODS: 471 male and female players (mean age 16,6 ±0,9, 54% female) from ten handball-profiled high schools completed a pre-season shoulder function screening as well as a baseline questionnaire about handball experience, former and present injuries based on the OSTRC Overuse Injury Questionnaire and a psychometric profile. Cross sectional data from the baseline questionnaire is presented in this abstract. Shoulder problems are defined as pain, ache, instability, stiffness, looseness or other complains related to the shoulder. Substantial shoulder problems are defined as shoulder problems leading to moderate or severe reductions in sporting performance or training volume, or a total inability to

participate RESULTS: The pre-season questionnaire showed that 41% had a history of shoulder problems, 28% had shoulder problems during the previous season and 12% reported substantial shoulder problems during the previous season. Shoulder problems were most common among female players (OR 1.6 95% CI, 1.1-2.4), backcourt players (OR 2.3, 95% CI 1.3-4.1) compared to wing players and among 2nd (OR 2.6 95% CI, 1.4-5.0) and 3rd (OR 3.6 95% CI, 1.7-7.6) year high school students compared to 1st year students. Most common onset of shoulder problems was gradual onset (70%), onset due to pulled in the arm (18%) and fall on arm (8%). CONCLUSIONS: The prevalence of shoulder pain among Swedish elite adolescent handball players is high and higher among female players, backcourt players and 2nd and 3rd year high schools students. These results are equal to the prevalence seen in senior male players.

P1-B-21 Shoulder strength among healthy adolescent elite handball players

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BACKGROUND AND AIM: Recent studies have suggested reduced shoulder strength and range of motion to be risk factors for shoulder injuries among handball players. Normative data on adolescent elite handball players are lacking, therefore the aim of this study was to present data for gleno-humeral strength in such a population. METHODS: In this study 342 healthy players, from ten different handball profiled high schools in Sweden (mean age 16.5 ±0.9, 53% female) were tested for gleno-humeral isometric external rotation (IER), isometric internal rotation (IIR) and isometric abduction (ABD) strength and eccentric external rotation strength (EER). The strength tests were performed during the pre-season preparation period 2014 and 2015 with a handheld dynamometer (MicroFet2). The players were tested twice in each position and the maximum values were used for analysis. All the tests were performed with the same test leader. To assure sufficient reliability of the strength measurements we performed a reliability study with 30 study participants and two testers prior to the original study, measuring inter- and intra-tester reliability. RESULTS: The intra-tester reliability in the reliability study was excellent for all of the tests (ICC 0.93-0.99), whereas the inter-reliability was excellent for ABD, IER and IRR (ICC 0.92-0.98) and good for EER (ICC 0.87). Our main results showed significant age and playing position difference among male players but not among female players. When normalized to body weight and BMI, male players were stronger compared to female players. Detailed results stratified by playing position and age as well as results normalized to body weight and BMI will be presented at the conference. Also strength ratios will be presented. CONCLUSIONS: This study describes data on shoulder strength among healthy adolescent elite handball players. This could be helpful for clinicians in the assessment of shoulder strength in healthy and injured adolescent handball players. All of the shoulder strength test showed acceptable reliability for clinical use.

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P1-B-22 Comparison of biomechanical charactertistics of rowing performance between elite and non-elite scull rowers: a pilot study

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BACKGROUND AND AIM: It has been shown that coordination, timing, balance and rhythm of rowing motion are core factors to enhance rowing performance (Baudouin & Hawkins, 2004; Buckeridge et al., 2015; Smith & Spinks, 1995). This study aimed to examine the characteristics of joint kinematics and synchronicity of rowing motion between elite and non-elite rowers. METHODS: Two elite (22 years, 192 cm, 87.4±2.5 kg)and two non-elite rowers (26.5±0.5 years, 185.6±0.2 cm, 91.2±3 kg) performed rowing stroke (3 trials, 20 strokes per each trial) at three different stroke rates (20, 30, 40 stroke/min) on stationary rowing ergometers. The rowing motions of two rowers were captured at once using a 3-dimentional motion analysis system (8-infrared camera VICON system, Oxford, UK). The range of motion (RoM) of knee, hip, and elbow joints on the sagittal plane, the lead time (TLead) and the elapsed time of the drive phase (TDrive) for each joint, the elapsed time for the knee joint to maintain fully extended position (TKnee) during the stroke were analyzed and compared between elite and non-elite rowers. Using mann-Whitney U test, these data were compared between two groups. Synchronicity of the rowing motion within and between groups was examined using coefficients of variation (CV) of the TDrive for each joint. RESULTS: Regardless of the stroke rate, the RoM of all joints were greater for the elite compared with non-elite rowers, except for the RoMs of the knee joint at 30 stroke/min and the elbow joint at 40 stroke/min ($p < .05$). Meanwhile, the TLead at all stroke rates were same between the groups. The TDrive for each joint were shorter for the elite compared with the non-elite. During the drive phase, elite rowers kept the fully extended knee longer than non-elite rowers ($p < .05$). The CV values of the TDrive within each group are smaller for the elite compared with the non-elite, except for the CV values of the hip at all stroke/min and elbow at 40 stroke/min (Table 1). CONCLUSIONS: Based on the results, greater RoM and the same TLead with shorter TDrive were observed for the elite compared with non-elite rowers, indicating that the elite rowers were capable of performing more powerful rowing stroke at the given stroke rate. Consequently, the rowing strategy of elite rowers would be more efficient to transmit higher power and accelerate the boat than that of the non-elite rowers. Regarding the synchronicity of rowing stroke, two elite rowers showed better synchronous performance than non-elite rowers (Table 1.) at the knee and elbow joints. Higher CV values and the larger RoM of the hip joint for the elite compared with non-elite rowers, might indicate that elite rowers use their own coordination strategies linking the lower and upper body motion at the hip-trunk region.

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P1-B-23 Effect of cryotherapy on eccentric exercise-induced muscle damage: a randomized clinical trial.

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INTRODUCTION AND AIM: Exercise-induced muscle damage provokes the installation of an inflammatory process that results in a sensation of pain and discomfort in individuals. Recently cryotherapy has been used as a strategy to recover from exercise-induced muscle damage, such as after training or competition. Thus, the present study aims to assess the effect of cryotherapy on eccentric exercise-induced muscle damage. METHODS: This is a randomized clinical trial composed of 40 women (22.8±2.2 years), randomly divided into two groups: control group and cryotherapy. Both groups underwent three assessments, all composed of algometry, dynamometry (peak torque normalized by body weight) and electromyography (root mean square and median frequency). After initial assessment, all the participants were submitted to an eccentric exercise protocol on an isokinetic dynamometer (2 series of 10 maximum eccentric contractions of non-dominant elbow flexors at 60°/s). Next, participants were submitted to the interventions, according to the pre-determined group: the control group did not undergo any intervention and remained at rest for 25 minutes; the cryotherapy group remained seated on the isokinetic dynamometer and a 1kg ice pack was strapped over the entire brachial biceps muscle and adjacent muscles of the arm under study using a bandage. Application lasted 25 minutes and a digital thermometer (Salvterm® 1200K, Brazil) with interface was used to measure cutaneous temperature and ensure cooling level. After the interventions each subject underwent two re-assessments: immediately (post) and 48 hours after the interventions, identical to the first one. SPSS for Windows (version 20.0) was used for all statistical analyses. A mixed design ANOVA (3x2) was used to investigate changes in algometry, peak torque normalized for body weight, median frequency and RMS. A 5% significance level was used ($p< 0.05$). RESULTS: In relation to algometry, a significant difference was observed for the control and cryotherapy groups, with a statistical difference at 48hr compared to pre and immediate post ($p<0.01$). However, no intergroup difference was observed ($p=0.15$). Analysis of peak torque normalized for body weight had altered values for both groups, demonstrating a difference at pre to immediate post and 48hr ($p<0.01$), but no intergroup difference ($p=0.77$). Analysis of electromyographic variables shows that median frequency was a significant difference in cryotherapy group, demonstrating an intragroup difference at post to pre and 48hr and intergroup difference between post ($p<0.01$). The electromyographic amplitude revealed no significant difference between pre, immediate post and 48hr after intervention in the two groups assessed ($p>0.05$) or any intergroup variation ($p=0.76$) (Figure 1). CONCLUSIONS: The cryotherapy with ice pack do not interfere in the response to eccentric exercise-induced muscle damage to any variable analyzed to brachial biceps.

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P1-B-24 Effect of whole body vibration on isokinetic performance and muscle activation of the quadriceps femoris: a randomized controlled trial

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Background and aim: Whole body vibration (WBV) has become a popular practice in training and rehabilitation centers. It works by a mechanism that produces vibrations in a combination of frequencies and amplitudes that are transmitted to the body in the form of mechanical energy in order to cause an increase in muscle recruitment by reflex triggered contractions. Despite being a widely used resource, there is a gap to be filled in the literature about the acute neurophysiological responses in skeletal muscle after WBV. This study analyzed the immediate effects of WBV with two distinct frequencies on neuromuscular performance of the quadriceps femoris of healthy subjects. Methods: 60 physically active women were submitted to an evaluation of isokinetic performance and surface electromyography of knee extensor muscles of the non-dominant limb. The variables analyzed were total work, average power and the root mean square (RMS) of vastus lateralis muscle. Immediately after the evaluation, intervention protocols were carried out. Subjects were randomly divided into three groups: group 30 Hz - performed an exercise protocol which consisted of staying barefoot in unipodal support on the non-dominant limb in the center of the vibrating platform, with 40o of knee flexion, while the upper limbs were extended at shoulder level and the trunk was kept in the upright position. The participants performed a total of 10 sets of 30 seconds, with rest intervals of 30 seconds between sets. The angle of the knee was monitored throughout the protocol with a universal goniometer to ensure that there were no changes in the amplitude. The vibrating platform was configured at a vibration frequency of 30 Hz and a vertical displacement amplitude of 4 mm; 50 Hz group - performed the same exercise protocol, but with the platform programmed at a frequency of 50 Hz and 4 mm of amplitude and control group - performed the exercise protocol with the platform off. The software SPSS (20.0) for windows was used for statistical analysis. A one-way ANOVA test was used to investigate baseline differences between groups. A two-way ANOVA for repeated measures was calculated to identify differences within and between pre- and post-tests. In the case of significance, post hoc comparisons (Bonferroni) were calculated additionally. A significance level of 5% was chosen. Results: No significant differences in anthropometric measures or variables analysed were observed in the baseline between the groups. There were no significant differences in total work, average power nor in the value of the RMS in any of the groups. Conclusion: The results of this study suggest that the exercise protocol associated with WBV is not able to significantly improve the neuromuscular performance of the quadriceps femoris of healthy subjects.

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P1-B-25 Immediate effects of stretching exercises on the electromyographic activity of hamstring muscles, before and after performing physical activities: a randomized controlled trial

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Background and aims: The realization of stretching before physical activity, training or sports competition is widely used in protocols in order to increase muscle flexibility and reduce the risk of injury. This study compared the acute effects of static stretching before and after isokinetic exercise, on electromyographic activity of the hamstrings. Methods: Eighty volunteers of both genders (age: 22.52 ± 2.6 years, BMI: 23.86 ± 3.2 kg / m) were randomized into 4 groups: control group (CG) just held the isokinetic exercise protocol (EP) for flexion-extension of the knee; Experimental Group 1: stretching (2 sets of 30 seconds of static auto-stretching of the hamstrings muscles) before the EP; Experimental Group 2: stretching after the EP and experimental group 3: stretching before and after the PE. To record the electromyographic activity, electrodes were placed according to the recommendations of the SENIAM for the biceps femuris (BF) and semitendinosus (ST) muscles. All subjects were positioned in the dynamometer and submitted to 5 maximal concentric contractions of knee flexors. The analyzed variable was the root mean square (RMS). A Kolmogorov-Smirnov test was applied to verify the normality of the data. A two-way ANOVA with Turkey post-hoc tests was applied to identify differences between groups. A significance level of 5 % was considered. Results: The electromyographic activity of Biceps Femoris (BF) and Semitendinosus (ST), after the intervention, presented a significant decrease in all the groups ($p<0,01$), but without significant differences between them. Conclusion: The realization of static stretching before and after an isokinetic exercise, does not alter the electromyographic activity of the hamstring.

P1-B-26 Examination of Lower Limb Ambidextrous Execution of the Snap Down Technique in Folk Style Wrestling

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BACKGROUND AND AIM: Folk style wrestling is the most popular form of wrestling in U.S high schools and universities. An important skill in folk style wrestling is the snap down, a skill that allows the wrestler to takedown the opponent from a standing position effectively.

However, there is a lack of scientific literature that examines the kinematic motions of the snap down technique bilaterally. Understanding athletic ambidexterity is an important factor in athletic performance and injury prevention, particularly in wrestling as it enables athletes to coordinate and perform the skill from both sides of the body efficiently and safely. Therefore, the purpose of this research study was to bilaterally examine the kinematic motions of the lower extremity in the snap down technique. METHODS: Five male college wrestlers volunteered to participate in the study and signed a University-approved consent form. Joint reflective markers were placed on both sides of lower extremity at the shoulder, hip, knee, ankle and toe. The participants performed five snap downs with the dominant (right) arm and another five snap down with the non-dominant (left) arm against an opponent who was equipped with wresting gear. A camera captured the sagittal view of the snap down motion and a standard two-dimensional kinematics analysis was conducted using Ariel Performance Analysis System software. RESULTS: A paired sample t-test was conducted at á = 0.05 to examine differences between the kinematics of right and left hip, knee and ankle joints. The results of the study showed no statistically significant differences between right and left legs in hip, knee and ankle joint angles and velocities at the point of head impact with the mat. The only significant difference (p = 0.02) was in the angular acceleration of the ankle between right (1186.9 ± 498.9 °/s/s) and left (-380.8 ± 568.2 °/s/s) legs. Additionally, on the right leg, the wrestlers showed a positive angular velocity and positive angular acceleration in all three joints, indicating that the motion of the snap down was extending and speeding up. Conversely, the wrestlers showed a positive angular velocity but a negative angular acceleration in all three joints (i.e. extending but slowing down) on the left leg, indicating that the execution on the left non-dominant leg did not continuously accelerate through the point of impact, suggesting a lack of follow through on left leg. CONCLUSIONS: This finding suggests there may be a lack of muscle strength deficit and/or a level of unfamiliarity with non-dominant (left side) execution of the snap down. Hence, emphasis on ambidextrous execution of motor skills should focus on the non-dominant limb for sports performance improvement. Future studies are warranted to further examine similar sports skills and provide a comprehensive understanding of ambidexterity in sport skills.

P1-B-28 Kinesio Taping promotes neither immediate nor delayed changes in neuromuscular performance in healthy, active women

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BACKGROUND AND AIM: Kinesio Taping (KT) is an elastic bandage that aims to improve neuromuscular performance, although there is no consensus as to its benefits. In practice, this technique has been widely used by healthy people in order to prevent injuries and

increase neuromuscular performance, seeking better performance during physical activities, whether at the professional or amateur level. Thus, the purpose of the present study is to analyze the immediate and delayed effects of KT application on electromyographic activity of the vastus lateralis and isokinetic performance (total work) in healthy subjects. METHODS: This is a randomized controlled trial. Sixty women with a mean age of 22.2±3.6 years and BMI of 22.5±2.3 Kg/m2 were divided into three groups: control, with ten minutes of rest (control, n=20), application of Kinesio Taping without tension (placebo, n=20) and with tension (KT, n=20) on the quadriceps. The primary outcome was the electromyographic activity (root mean square) while secondary outcome was isokinetic performance (work). An 8-channel signal conditioning module with 16-bit resolution (TeleMyo Transmitter, Noraxon Inc., Scottsdale, AZ, USA) was used for signal acquisition and common mode rejection ratio (CMRR) >100 Db. Signals were captured on a sampling frequency set at 1500 Hz, filtered at a frequency between 10 and 500 Hz and amplified 1000 times. A computerized isokinetic dynamometer (Biodex Multi-Joint System 4, Biodex Medical Systems Inc., Shirley, NY, USA) was used to isokinetic performance evaluation (total work). The evaluations were performed at five distinct time points: before the intervention protocol (pre), immediately after (post), and 24h, 48h, and 72h after the intervention protocol. The last evaluation (72h) was performed 24h after the removal of KT. Estimates of average effect (differences between groups) for all variables were calculated using the ANOVA mixed model. This analysis model incorporated the intervention groups (control, placebo, and kinesio taping), time (pre, post, 24h, 48h, and 72h), and the group × time interaction. A significance level of 5% was adopted for all statistical analyses. RESULTS: No difference was detected between the groups in the assessments for the variables: VL muscle RMS (F=1.226, p=0.28) and total work (F=0.534, p=0.76). The results indicated that the application of KT does not promote immediate or delayed changes to electromyographic amplitude of VL or the average power of knee extensors. CONCLUSIONS: KT promotes neither immediate nor delayed changes in muscular performance of the femoral quadriceps in healthy women.

P1-C-29 Quantification of the expression of the flexion synergy using reach kinematics in pediatric hemiplegia

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BACKGROUND AND AIM: Pediatric hemiplegia (PH), which results from an early brain injury including pediatric stroke, causes weakness and movement impairments primarily on one side of the body. Based upon the developmental progression of the nervous system, injury timing may impact the presentation of motor impairments due to altered descending nervous system control. Previous isometric work has demonstrated weakness and the

expression of upper limb synergies based upon timing of injury. Earlier injuries (pre-natal) may result in the maintenance of usable direct corticospinal connections for motor control whereas later injuries (post-natal) may lead to the reliance on more diffuse brainstem pathways such as the reticulospinal tract which may result in abnormal coupling of shoulder abduction with elbow, wrist, and finger flexion. As a result of this coupling, reaching and hand opening while lifting the weight of the limb is expected to be compromised more in those with post-natal injuries compared to those with pre-natal injuries. Limitations to accurate control of the limb to complete a task such as reaching can sizably limit a growing child's ability to interact with the world. Deficits in elbow extension, a main functional limitation to reach in PH, have been observed using 3D kinematics of the grasp and reach cycle. However, previous methods have not explored the factors contributing to the observed deficits. The aim of this study is to quantify the kinematics of the shoulder, elbow, and fingers during a dynamic reaching/grasping task as a function of shoulder abduction loading. METHODS: Using an admittance-controlled robotic device supporting the forearm, shoulder abduction loading is modulated by a percentage of maximum voluntary torque while the subject reaches forward and attempts to open the hand. Shoulder, elbow, and finger range of motion are recorded throughout the reach at each load level. By increasing the neural drive required to complete the task, this experiment probes at the limitations and differences in motor control between subjects who were typically developing and those with pre- and post-natal brain injuries resulting in PH. RESULTS: Preliminary findings show a significant reduction in reaching range at higher shoulder abduction loading levels in a prenatal individual. It expected that similar reduction in reaching range of motion will be seen at lower abduction loading levels in post-natal individuals. CONCLUSIONS: Quantifying reach and hand kinematics as a function of shoulder abduction loading enriches the understanding of altered motor control in PH as a function of time of injury. This is an imperative step for the development of more targeted and effective interventions to improve functionality in the subsets of this population.

P1-C-30 Priming the motor cortex by electrical stimulation of back muscles

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Peripheral electrical stimulation (PES) of limb muscles enhances excitability of the corticospinal pathway and is thought to aid motor learning. This may have application in rehabilitation of back pain, but has not yet been studied for trunk muscles. Recent research suggests differential effects of PES on the corticospinal excitability when applied to muscles of the leg and hand and for different muscles in the leg. For instance, unlike other leg muscles, excitability of spinal, but not cortical, inputs to the soleus muscle is increased after

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PES. This differential response suggests the mechanisms that regulate plasticity are muscle-dependent, and might be explained by the functional role of the muscles. For example, corticospinal inputs to postural muscles may be less affected by PES than muscles generally involved in voluntary tasks. As back muscles share an important role with soleus in postural control is possible that corticospinal inputs to lumbar muscles might be less amenable to the effects of PES than arm muscles. This study aims to investigate whether PES of back muscles changes excitability of corticospinal inputs to back muscles. 12 volunteers with no history of LBP. Pairs of intramuscular fine-wire were used to record myoelectric activity from deep multifidus (DM) and erector spinal at level of L3 (LES). Surface electromyography electrodes were used on lumbar multifidus at L5 (LMs), erector spinae at L3 (LESs), obliquus internus abdominis (OI), obliquus externus abdominis (OE). Transcranial magnetic stimulation was used to test corticomotor excitability (single pulse) and the short-interval intra-cortical inhibition (SICI) and long-interval intra-cortical facilitation (LICF) of corticospinal projections to DM. Active motor threshold (aMT) to evoke a motor evoked potential (MEP) in DM was determined and stimulation applied at 120% of this intensity. PES was provided via electrodes placed over the right multifidus. 20-min application of PES was set at intensity to induce a muscle contraction, 30 Hz of frequency and ramped at a rate of 6 surges-per-minute to mimic functional activation of the muscle. Mean aMT for DM was 42.7 + 10% of maximal stimulator output. Pairwise comparisons of MEP amplitude to single pulse paradigm did not indicate statistically significant effects for all trunk muscles examined. The effect sizes for DM and LES were found to be either ?neglegible? or ?small? for the rest of the muscles assessed muscles. No evidence also of changes in SICI or LICF; conditioned MEP amplitude was not different between trials after PES. This study show that PES of the paraspinal muscles seem less prone to induce changes in excitability of corticospinal inputs to the trunk muscles or modulate cortical facilitatory and inhibitory mechanisms. This suggests PES might be difficult to be used to ?prime? the paraspinal muscle system for motor learning. We propose a reduced efficacy of PES to influence cortical inputs to postural muscles

P1-C-31 Effect of Movement Velocity on Hip and Knee Muscle Onset Latency During a Single Leg Squat in Sunjects with and Without Patellofemoral Pain Syndrome

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BACKGROUND AND AIM: Patellofemoral pain syndrome (PFPS) is one of the most frequent diagnosis and it is described as an orthopaedic enigma. Several studies have evaluated lower limb muscle activity and onset latency during functional movements, but they have not considered movement velocity as an influential factor in movement performance. Therefore,

the aim of this study was to find differences on hip and knee muscle onset latency between subjects with and without PFPS, and if these are accentuated at different velocities of a single leg squat (SLS). METHODS: In this case-control study participated 22 women (11 PFPS and 11 healthy). Surface electromyography (EMGs) was used to evaluate muscle onset latency of gluteus maximus (GM), anterior gluteus medius (AGm), posterior gluteus medius (PGm), rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL), and biceps femoris (BF) during 3 repetitions at high velocity (HV) and low velocity (LV) of a SLS. A two-way repeated measure ANOVA with factors: velocity (2 levels) and diagnosis (2 levels) was performed to each muscle onset latency. When statistical differences were observed, Bonferroni corrected t- tests was used. A paried t-test was used between levels when differences of a single factor (velocity or diagnosis) were observed. An alpha level < 0.05 was considered. Partial eta squared (ηp2) and Cohen´s d were used to calculate effect size. RESULTS: No interaction effect was observed between velocity and diagnosis for any muscle onset latency, although statistically significant differences were found to velocity factor for GM (F1 = 11.634; P = 0.035; ηp2 = 0.538) and AGm (F1 = 10.337; P = 0.045; ηp2 = 0.508), with a large effect size in both cases. Statistically significant differences were found between LV and HV for GM in PFPS group (P = 0.004; d = 1.016) and healthy group (P = 0.0215; d = 1.124), and for AGm in healthy group (p=0.0345; d= 0.849), with a large effect size for each case. CONCLUSIONS: GM and AGm showed an earlier onset latency at LV of a SLS for healthy and PFPS groups. Therefore, SLS performance velocity could affect hip onset latency regardless of subject condition. This could be considered by physical therapist and health professionals to evaluate the neuromuscular condition of these muscles in clinical field. Future studies should include a larger sample, another EMGs measures like muscle amplitude or recruitment order, that allow to explain the absence of differences between PFPS and healthy subjects.

P1-C-32 Contributions of vestibular and somatosensory systems to quiet standing in sighted and congenitally blind people

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BACKGROUND AND AIM: Congenitally blind people may have a different strategy to maintain balance in quiet standing, but the mechanism has not been fully explored. This pilot study was conducted to compare the contributions of the vestibular and somatosensory systems to quiet standing in blind and sighted people. METHODS: A total of 4 young adults (2 sighted (eyes closed) and 2 congenitally blind) participated in the study. Each subject stood (30 sec / trial, 3 trials / condition) bipedally under the following 4 conditions: hard floor with neutral head position (HN), hard floor with head extension (to reduce the input from the vestibular system, HE), soft floor (to reduce the input from the somatosensory

system) with neutral head position (SN), and soft floor with head extension (SE). The head stability and center of pressure were measured using an accelerometer attached to the head and a force plate, respectively, in the anterior-posterior and mediolateral directions (Acc-AP, Acc-ML, COP-AP and COP-ML), and root mean square (RMS) amplitude of these signals were analyzed. RESULTS: At baseline (HN), most of the signals were similar between groups, but some were smaller for the blind subjects than those of the sighted subjects. For example, the Acc-AP was 0.057 (0.040 and 0.074), mean (2 subjects) m/sec and 0.107 (0.106 and 0.107) m/secc for the blind and sighted subjects, respectively. When the values from the 3 conditions (HE, SN and SE) were divided by the corresponding values from HN, the clear between-group difference was found only in the Acc-AP. Sighted subjects were able to maintain the head stability even at the most challenging condition (Acc-AP at SE = 1.01 (0.79 and 1.24)) although the COP-AP greatly increased at SE (2.47 (2.42 and 2.53)). In contrast, both the Acc-AP and COP-AP increased in the blind subjects (Acc-AP = 2.47 (2.44 and 2.50) and COP-AP = 4.26 (3.75 and 4.76)). CONCLUSIONS: These data suggest that blind people can maintain balance comparable to that of sighted people with no vision by depending more on the remaining two sensory systems, and the priority for head stabilization may differ for sighted and blind people.

P1-C-33 Decomposition of gyroscopic trunk sway for clinical assessment of standing balance

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It has been shown that movement of centre of pressure (COP) measured with a force plate during quiet stance can be decomposed into a low (rambling, Rm) and a high frequency component (trembling, Tr). The trembling component is highly correlated to the horizontal forces on the force plate (Fh), whereas the rambling component is not (Zatsiorsky, 1999). This suggests that they originate from different sources, a supraspinal and a spinal reflex, that each give clinically important information about balance (Solnik, 2014). The aim of this study was to develop and evaluate a method to decompose gyroscopic signals measured at the trunk during quiet stance to increase the clinical applicability of the method. Standing balance was measured repeatedly (n=6) on eight healthy subjects (age 41±7 years, weight 71±3 kg, 4 males). Measurements were simultaneously performed on a force plate and using a gyroscopic equipment mounted at the lower back close to the centre of mass (COM) measuring trunk sway in anterior-posterior direction. Rambling (plate_Rm) and trembling (plate_Tr) were decomposed from the stabilogram according to (Zatsiorsky, 1999, 2000). Trunk angular acceleration ($\ddot{x}$) was derived from the gyroscopic angular velocity ($\dot{x}$) and trunk angle (x) by integration of $\dot{x}$. A decomposition was based on $\ddot{x}$ =0, where the sum of all forces

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on the subject was considered to be zero. Gyro_Rm was constructed by a cubic spline between each point in x where ẍ =0, and gyro_Tr was x minus gyro_Rm. ẍ was filtered with a 4th order zero-phase Butterworth low pass filter at 2Hz. The cross correlation between Fh and plate_Tr was high, reproducing the results of (Zatsiorsky, 1999) with a mean corr. coef. of 0.90±0.04. The corresponding result for the gyro system was 0.17 ±0.20 and the corr. coef. between plate_Rm and gyro_Rm was 0.45±0.46. Also the agreement of RMS was low both for Rm and Tr with corr. coef. 0.46 resp. 0.25. The RMS amplitudes from the force plate were significantly higher for Rm and Tr compared to the gyro, two and six times respectively. If the human body movement during quiet stance could be completely modelled as an inverted pendulum, information from the balance control process should be found by measuring trunk sway as well as forces on a force plate. The low correlation between plate_Rm and gyro_Rm show that movement only at the trunk level inadequately describes the COM trajectory. For some persons the correlation was high, but in others knee and hip joints are likely to have impaired the pendulum movement. The amplitude of gyro_Tr was also much lower than that of plate_Tr. Thus, frequencies above 0.4 Hz are damped at the trunk. The movement of COP and COM have been found to correlate well when estimating COM from the whole body (Winter, 1995). Our study shows that a single wearable sensor on the back is not sufficient, but additional sensors on other body parts might enable better estimates of the Rm and Tr components of standing balance.

P1-C-34 Relationship between center of pressure and medio-lateral directions in the functional reach test: clinical projection in spinal cord injury

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BACKGROUND AND AIM: Individuals with a Spinal Cord Injury (SCI) often experience various degrees of motor or sensory impairments that can affect their trunk as well as their Upper Extremities (U/E) and lower extremities depending on the neurological level and the completeness of the injury to the spinal cord [1]. Postural balance is characterized using the displacement of the center of pressure (COP), in standing or sitting position [2,3]. Postural outcome measures commonly used to quantify postural balance include time and frequency domain parameters to measure the displacement, velocity, area and frequency characteristics of COP fluctuations over time [4]. Interpreting the results of postural balance assessment can be difficult to manage in clinical environments, particularly within SCI rehabilitation programs due to the large data set that can be extracted from the COP. A simple method that allows for straightforward interpretation is needed for quantifying seated postural balance in clinical populations. Modified Functional Reach Test (mFRT) was designed to assess sitting balance in individuals with SCI [5]. The aim of the current study was to evaluate the relationship

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between seated balance function parameters based on COP and the mFRT in individuals with SCI complete. METHODS: Cross-sectional study. Twelve (individuals with SCI, according to American Spinal Injury Association (ASIA) grade A (11 males/1female; range 20-42 years; 2 tetraplegia, 4 high paraplegia and 6 low paraplegia). Individuals were tested using a force platform (AMTI OR67 and processing with Matlab R2012) during the quiet sitting position and the mFRT with/without force plate in the anterior, right lateral and left lateral directions. The sway parameters investigated were the area COP sway (COP-Sway), the average velocity of COP displacements along the anterior-posterior (COP-VAP in), and medial-lateral (COP-VML) directions and standard deviation in both directions (SD-AP and SD-ML). COP units and mFRT were expressed in centimeters, respectively. Pearson correlation test was used, ($p \leq 0.05$). RESULTS: The statistical analysis revealed moderate and large correlations between COP and mFRT in the medio-lateral directions (p less than 0.01). COP-Sway (r=0.64), SD-AP (r=0.60), SD-ML (r=0.64) and COP-VML (r=0.69) with mFRT right lateral direction. COP-Sway (r=0.82), SD-AP (r=0.58), SD-ML (r=0.74) and COP-VML (r=0.71) with mFRT left lateral direction. CONCLUSION: mFRT medio-lateral direction can be used as a clinical assessment instrument of the seated postural balance in people with SCI complete. [1] Sprigle et al. J Spinal Cord Med. 2003 Fall;26(3):236-43. [2] Galli et al. Mult Scler Relat Disord. 2015;4(6):594-7. [3] van Dieën et al. Gait Posture. 2010;31(1):42-6. [4] Grangeon et al. J Bioengineer & Biomedical Sci 2013;3: 124. [5[Harel et al. J Spinal Cord Med. 2013;36(2):127-33.

P1-C-35 Effect of body weight support on muscle activities during walking and running using a lower body positive pressure treadmill in healthy adults

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BACKGROUND AND AIM: Lower body positive pressure treadmills that can unload body weight have been recently used as a rehabilitative and training tool for individuals after sports injury and patients with gait disorders. In this study, the changes in muscle activities during walking and running on the treadmill with various levels of body weight support were investigated in healthy adults. In particular, we focused on the differences between gait modes (walking and running) at a given speed and among various muscles in terms of the effectiveness of body weight support on the muscle activity. METHODS: Healthy adult subjects performed walking and running at the same speed (6 km/h) on a lower body positive pressure treadmill at 5 levels of body weight support (100%, 80%, 60%, 40%, and 20% of their body weight). The level of body weight support was computer-regulated by changing the air pressure in the chamber of the treadmill. The body weight support conditions were randomly changed. The duration of each body weight support condition during walking and running was set for 2 minutes. To assess the level of muscle activity

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during treadmill exercise, surface electromyographic (EMG) activities in the muscles of the lower limb and trunk were recorded by a wireless system. RESULTS: The muscle activation pattern in each muscle was largely preserved at all 5 levels of body weight support during the exercise of walking and running. In the soleus muscle, significant difference was observed in the muscle activation level between the gait modes and among the body weight support conditions. Increased levels of body weight support caused greater decreases in the muscle activity in both gait conditions. In contrast, the EMG activities in the medial gastrocnemius muscle were not significantly affected by body weight support, although there was a significant difference in the muscle activities between the gait modes. The EMG activities in the latissimus dorsi, gluteus maximus, rectus femoris, and vastus medialis muscles were also decreased by increased body weight support. In the vastus medialis muscle, a marked decrease in the muscle activity caused by the body weight support was observed during running. In contrast, increased body weight support to 60% during both gait modes did not decrease muscle activities in the biceps femoris and tibialis anterior muscles. CONCLUSIONS: These results showed that the effect of body weight support on the muscle activation level differed among the muscles and between the gait modes at a given speed. These data might be useful for designing effective rehabilitation programs.

P1-C-36 The effect of acute pain and motor learning on sensorimotor integration and accuracy using a motor tracing task

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[1]UOIT

BACKGROUND AND AIM: Previous work demonstrated differential <changes in early somatosensory evoked potentials (SEPs) when motor learning occurred in the presence of experimental cutaneous pain, however the learning task was insufficiently complex to determine how these underlying neurophysiological differences impacted learning acquisition and retention. In order to address this limitation, we have developed and validated a novel and complex motor tracing task to be used in this study. Thus, the overall aim of this study was to investigate the interactive effects of acute pain on motor learning and sensorimotor integration (SMI) using a novel and complex motor tracing task. METHODS: Two groups of twelve participants (N= 24) were randomly assigned to either an intervention (capsaicin cream) or control (inert lotion) group. SEP amplitudes were collected at baseline, post-application and following motor learning. Participants performed a motor tracing task followed by a pain-free retention task within 24-48 hours while accuracy data was recorded. RESULTS: The P25 SEP peak differed significantly ($p<0.05$) following the application of capsaicin cream. For the control group, the N20 SEP peak significantly increased ($p<0.05$) while the amplitude of the N24 SEP peak significantly decreased ($p<0.001$) following motor learning. The N30 SEP peak was significantly increased ($p<0.001$)

following motor learning for both groups. Both the control (p<0.001) and intervention (p<0.001) groups improved in accuracy following motor learning. The control and intervention groups differed from each other at baseline (p<0.05), following motor learning (p<0.05), and approached significance at retention (p=0.06) with the intervention group outperforming the control group. CONCLUSIONS: The improved performance at baseline and following motor learning acquisition in the presence of capsaicin provides support for the enhancement of motor learning while in acute pain. In addition, the changes in SEP peak amplitudes suggests that early SEP changes are markers of SMI alterations accompanying motor learning which are negated with mild acute pain.

P1-C-37 Effect of neuromuscular electrical stimulation on motor cortex excitability upon release of tonic muscle contraction

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BACKGROUND AND AIM: The immediate onset of muscle relaxation following voluntary muscle contraction is a normal process in healthy subjects when they engage in centrally controlled motor activity, and it is important especially in activities (e.g., reaching) requiring precise temporal modulation and force output. Imaging studies have revealed that voluntary muscle release from an active contraction is preceded and accompanied by activation of the primary and supplementary motor areas. However, precisely how these multiple brain activities lead to termination of lower motoneuron activity and mediate muscle relaxation remains unclear. Neuromuscular electrical stimulation (NMES) is commonly used to treat gait disturbance like ?foot drop,? and paresis of the hand muscle with motor neuron lesions. A peripheral afferent input by NMES leads to cortical reorganization and changes in cortical excitability, resulting in compensatory and novel motor functions. Using motor-evoked potentials (MEPs), produced by a single pulse of transcranial magnetic stimulation (TMS), and short-interval intracortical inhibition (SICI), we investigated motor cortex excitability upon the onset of voluntary muscle relaxation, immediately following a period of voluntary tonic muscle contraction. In addition, we studied the effect of afferent input?produced by neuromuscular electrical stimulation (NMES) during muscle contraction?on motor cortex excitation. Two intensities of NMES were tested: 1.2 times the sensory threshold and 1.2 times the motor threshold (MT). METHODS: Fifteen healthy individuals participated in the study. They were asked to execute constant wrist extension and to release this muscle contraction upon hearing an auditory ?GO? signal. MEPs were recorded from the flexor carpi radialis (FCR) and extensor carpi radialis (ECR), while TMS was applied during the tasks at three different time intervals (30, 60, and 90 ms) after the ?GO? signal. The timing, order of auditory signals, and stimulations were varied among subjects using Lab VIEW, ver.7.1.

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(National Instruments Corp.; USA). Electromyography (EMG) activity was simultaneously recorded from the right ECR and FCR muscles with surface electrodes (1.0-cm diameter). The EMG and force transducer signals were amplified using a filtered channel with gain (bandwidth 5?2,000 Hz for EMGs and 0.01?1,000 Hz for the force transducer), which was digitized with an analog-to-digital interface (sampling rate = 5 kHz). The sampling recording time was 800 ms, including the 100 ms preceding the time of presentation of the ?GO? signal (pre-analysis period). RESULTS: Motor cortex excitability was greater during voluntary relaxation of the ECR and FCR with high-intensity NMES, while the relaxation time was shorter. Each parameter showed significant changes between 30 ms and 60 ms. Additionally, in both muscles, SICI was larger during NMES than in the absence of NMES. CONCLUSIONS: We propose that terminating a muscle contraction t

P1-C-38 Trunk muscle activation during position-control tasks in sitting

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BACKGROUND AND AIM: There is conflicting evidence regarding the degree of antagonistic trunk muscle activation required during isometric loading of the trunk. Several studies show prominent agonist/antagonist co-activation in situations with direction specific loading to the trunk whereas others report negligible co-activation. Furthermore, it is difficult to predict the potential for directional preference of activation of the deeper trunk muscles, in particular transversus abdominis, largely due to the lack of extensive bony attachment and varying fibre orientation within the muscle. This study aimed to compare activity of a range of trunk muscles in an unloaded upright sitting position and between directions of tangentially applied external loads. METHODS: Healthy participants sat in an unloaded upright semi-seated position. Intramuscular EMG was recorded from eight abdominal and back muscles on the right side. Recordings were made at rest and while resisting moderate inertial loads applied to the trunk in eight different directions. EMG amplitude of each muscle was measured for 1 s prior to peak expiration and was normalized to the peak activation for that muscle across loading directions. RESULTS: The median activation of all muscles in the unloaded upright position ranged from 2.8 % to 23.8 % relative the peak across loading directions, and the antagonistic activation (defined as activation in the load direction opposite that of maximum activation for each muscle) for all muscles ranged between 1.7 % - 28.5 %. Deep multifidus had the lowest, and transversus abdominis the highest relative activation, in both the unloaded position and in the antagonist direction. Antagonistic trunk muscle activation above that required to maintain upright sitting, was not significant for any muscle in the loading conditions. Furthermore, all muscles, including the deeper trunk muscles, demonstrated a directional preference of activation. CONCLUSIONS:

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Antagonistic muscle activity of amplitude equivalent to that recorded in unloaded upright sitting is sufficient to maintain control of the spine during predictable and sustained loading tasks of low to moderate magnitude. The activation of all trunk muscles varies with direction of loading.

P1-C-39 Altered integration of proprioceptive information for balance control is linked with prospective falls

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BACKGROUND AND AIM: Compromised postural control contributes to falls risk. Age-related changes in sensory information processing reduce postural stability and could increase falls risk. This has not been tested prospectively. Effective postural control shows adaptable integration of sensory information with changing environmental conditions. Muscle-tendon vibration provides proprioceptive input, which evokes an illusion of muscle lengthening. Postural change to compensate for the muscle lengthening illusion is reflected in a centre of pressure (CoP) shift, and its magnitude depends the weighting placed by the nervous system relative to other sensory information regarding posture. In addition, postural control might be affected as proprioceptive information is less valid due to vibration. We aimed to compare the effect of triceps surea, lumbar and cervical erector spinae muscles vibration on CoP shifts, and CoP dynamics before, during and after vibration between a group of elderly individuals who reported one or more falls (fallers) in subsequent 12 months compared to people who reported no falls (non-fallers). METHODS: Participants (n=102; 75.3±5.5 years; fallers: n=44; non-fallers: n=62) stood on a force plate (blindfolded) for 3 trials of 135s. In each trial, mechanical vibration (60Hz) was applied twice to the calf, back or neck for 15s at 15s and 75s after start of recording. CoP mean displacement and relative displacements when vibrating different muscles were calculated. Windowed recurrence quantification analysis (RQA, size: 15s, overlap: 14s) with fixed recurrence rate (5%) was applied to characterise postural control before, during and after vibration. Differences in the dependent variables between groups were tested using wavelet-based t-tests. RESULTS: Mean and relative displacements of CoP during muscle vibration were similar between the groups. RQA showed lower deterministic structure, lower entropy and lower laminarity in fallers than non-fallers after cessation of the second ankle, and first lumbar vibration periods. Neck vibration did not show differences between groups. CONCLUSIONS: Overall, fallers and non-fallers were perturbed a similar amount by vibration at each location, which implies that there was no reweighting of proprioceptive input from any region. However, structure of CoP motion

after removal of vibration differed between groups which has several potential interpretations. This result could imply that non-linear measures provide a more sensitive evaluation of weighting applied to the proprioceptive input. Differences after second but not first ankle vibration could imply that fallers are less able to learn from exposure to the perturbing ankle vibration. In contrast, differences after first but not second lumbar vibration suggests the opposite. In summary, measures of structure of COP motion were related to prospectively-identified falls, but additional work is required to resolve the physiological interpretation.

P1-D-40 Spike timing-dependent plasticity in lower-limb muscles after incomplete spinal cord injury

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We previously demonstrated that repeated pairs of pre- and postsynaptic volleys arriving within a specific interval at the motoneuron pool of intrinsic hand muscles increase corticospinal transmission in humans with incomplete spinal cord injury (SCI). The extent to which this effect generalizes to lower-limb muscles is unknown. Here, we examined spike timing-dependent like plasticity (STDP) in the lower limb by targeting tibialis anterior (TA) motoneurones in individuals with chronic incomplete cervical SCI and in a group of control subjects. Two-hundred paired stimuli elicited by transcranial magnetic and peripheral nerve stimulation were delivered at 0.1 Hz. The resulting volleys were timed to arrive at the spinal cord to either facilitate (STDP%2B, presynaptic 2 ms before postsynaptic) or inhibit (STDP-, postsynaptic 15 ms before presynaptic) corticospinal transmission. We found that after the STDP%2B protocol, the amplitude of motor evoked potentials (MEPs) in the TA muscle elicited by magnetic stimulation of the motor cortex and electrical stimulation of the thoracic spinal cord were increased by ~80% ($p < 0.001$) and ~50% ($p = 0.02$), respectively. After the STDP- protocol, MEP amplitudes elicited by magnetic stimulation of the cortex and electrical stimulation of the spinal cord decreased by ~30% ($p = 0.002$) and ~20% ($p < 0.001$), respectively. In an additional experiment, participants produced repeated, brief isometric voluntary contractions of the TA before and after the STDP%2B protocol. Following paired stimulation, mean rectified electromyographic activity in the TA muscle and mean dorsiflexion force increased by ~25% ($p < 0.001$ and $p < 0.001$, respectively) in individuals with SCI. Our findings demonstrate that it is possible to elicit STDP-like mechanisms in residual corticospinal projections targeting lower-limb muscles after human SCI, which may complement therapeutic strategies intended to improve corticospinal control during locomotion.

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P1-D-41 Distributed stimulation to augment force evoked with functional electrical stimulation

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Background and Aim: Functional electrical stimulation (FES) involves artificial activation of skeletal muscle to restore motor function in paralyzed limbs. A major obstacle limiting use of FES, however, is the difficulty of generating sufficient muscle force. For example, FES systems applied to high-level tetraplegics require an external frame to support the arm because stimulation alone is insufficient to elevate the limb against gravity. Such weak contractions are not simply a consequence of muscle atrophy - indeed, the maximum force that can be evoked with electrical stimulation in healthy subjects is markedly less than that which can be generated voluntarily. One factor that might contribute to this force deficit is the highly distributed branching of intramuscular motor nerves. Such dispersion may make it difficult for a single electrode, as often used in FES, to activate the entire array of motor axons within a muscle. Therefore, the aim of this study was to determine whether stimulating a muscle with two current sources could boost force above that achievable with a single source. A secondary aim was to determine whether temporally interleaved stimulation between stimulation sites might reduce fatigue. Methods: Two tungsten electrodes were inserted into the anterior deltoid (~ 2 cm apart) of Rhesus macaque monkeys (n = 2). Monkeys were anesthetized, secured in a seated position with the test arm hanging in a vertical orientation. Shoulder flexion forces were recorded with a force transducer attached to the wrist. Surface electrodes served as return electrodes. Trains of pulses (1 s) were delivered repeatedly to one electrode at 35 Hz with current-pulse amplitude incremented in 1 mA steps until force output saturated. This process was then repeated for the other electrode. We then compared the force exerted during "maximal" stimulation delivered by each electrode individually to that generated by simultaneous stimulation through both electrodes. We then repetitively stimulated with 2-s trains for 4 min using one of three fatigue protocols with stimuli delivered at: 1) 35 Hz synchronously to both electrodes, 2) 17.5 Hz to each electrode but 180 degrees out of phase such that the stimuli to the two electrodes were interleaved, and 3) at 35 Hz to each electrode but interleaved. Only one protocol was tested per experimental session. Results: The two monkeys participated in a total of 29 experimental sessions. Overall, the force evoked by duel-electrode stimulation was 47±22% greater than that elicited with single electrode stimulation. Interestingly, however, there was no significant difference in fatigue across the three protocols (fatigue index: 0.33±0.08 synchronous 35 Hz, 0.29±0.06 interleaved 17.5 Hz, 0.26±0.14 interleaved 35 Hz). Conclusion: Distributed stimulation with more than one electrode offers a means to increase the force exerted with FES but does not appear to significantly reduce fatigue.

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P1-D-42 Long latency responses induced by Robotic Neuromodulatory Rehabilitation System for Paired Associative Stimulation

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BACKGROUND AND AIM: Paired Associative Stimulation (PAS) is a procedure that utilizes synchronously paired stimulation of the peripheral nerve and the brain. PAS can modulate motor cortical excitability and may thus facilitate the regaining of disabled motor function due to brain injury. The standard PAS uses electrical stimulation, but mechanical stimulation can be a better alternative. Since the timing between the central and peripheral nerve stimulations is essential in PAS, the aim of the study was to explore the feasibility of a new PAS modality using mechanical stimulation as the peripheral stimulation by examining the effective time window for synchronization. METHODS: Ten healthy subjects participated in this experiment. Robotic Neuromodulatory Rehabilitation System was designed and developed for applying mechanical stimulation as peripheral stimulation in a time-controlled manner. Mechanical stimulation was applied on the right wrist-flexor tendon. This mechanical stimulation did not induce long-latency stretch reflex by itself. As paired stimulation, transcranial magnetic stimulation (TMS) was applied to the motor cortex in the left hemisphere at various time intervals after the mechanical stimulation. For each time interval, ten neuromuscular responses (surface electromyogram, EMG) were analyzed from the flexor carpi radialis. 'Time window' was defined as the range of time interval in which four long-latency neuromuscular responses were observed out of ten. The number (range) of time intervals used in the experiment was different by each subject because each subject has different physiological characteristic. RESULTS: The time window (i.e. range of time interval that induced long-latency response by paired stimulation) was 55, 15, 15, 15, 30, 85, 100, 145, 80, and 50 ms for each ten-subject. A response was considered as long-latency response if its value was above certain threshold which is different by each. When the mechanical stimulation was replaced with electrical stimulation in one of the subjects (whose time window was 50ms), its time window was 20 ms. <CONCLUSIONS> The human subject experiments show the feasibility of Robotic Neuromodulatory Rehabilitation System for applying mechanical stimulation as a potential new modality in PAS. The range of time interval that induced long-latency response with the paired stimulation was varied for each subject. However there was certain range of time where we can expect long latency response. In looking at one subject data, mechanical stimulation appears to allow wider time window than that of electrical stimulation. A wider time window would indicate less timing constraints between TMS and mechanical stimulation timings. This is because the response to mechanical stimulation is more dispersed in time due to the desynchronized activation of muscle spindles compared to impulsive nerve response induced by electrical stimulation.

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P1-D-43 'Off-the-shelf' foot orthoses change knee load during walking in people with patellofemoral pain and mobile feet

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BACKGROUND AND AIM: Prefabricated or 'off-the-shelf' foot orthoses are frequently used in the management of patellofemoral pain (PFP), with clinical trials demonstrating their efficacy. However, mechanisms by which foot orthoses exert their therapeutic effects at the knee are unclear, especially in pain populations. Our previous work suggests that a subgroup of people with PFP, who have greater foot mobility, have a greater likelihood of success with foot orthoses. It is plausible that this subgroup may be more responsive to a mechanical foot intervention, and thus demonstrate more consistent changes in knee load in response to foot orthoses. This study explored whether people with PFP and mobile feet exhibit different effects on knee load when walking with foot orthoses, compared to shoes alone, than those with less mobile feet. METHODS: 36 people with chronic PFP (duration ≥3 months; 19 females; mean±SD age 36±7 years; BMI 25±4 kg/m2) participated in a within-subject, repeated measures immediate effects study. Midfoot width was measured at 50% of foot length, in weight bearing (WB) and non-weight bearing (NWB), and midfoot width mobility calculated as the difference between WB and NWB measures. K-means cluster analysis was used to classify participants into two homogenous groups based on midfoot width mobility (Group 1: 2.3-9.3mm; Group 2: 9.8-17.4mm). Gait data were collected during level walking under two conditions: (i) sandal (Nike Strap Runner); and (ii) sandal with prefabricated foot orthoses (Vasyli International), using a nine-camera VICON motion analysis system (Oxford Metrics) and three AMTI ground-embedded force plates. Peak external knee adduction moment (KAM; first peak) was calculated for each condition, and the average of three trials used. Paired t tests investigated differences in peak KAM between the shoe and orthosis conditions ($p < 0.05$), for each foot mobility group. RESULTS: Group 2 demonstrated a significant increase in peak KAM when walking with foot orthoses, compared to shoes (mean difference 0.03 Nm/kg, 95% CI 0.01 to 0.05, p=0.015). No significant difference was observed in Group 1 (0.002 Nm/kg, -0.02 to 0.02, p=0.855). CONCLUSION: In people with PFP, prefabricated foot orthoses appear to impart changes in frontal plane knee load during walking in those with greater midfoot width mobility, but not those with less mobility. The direction of change is favourable in a population that typically demonstrates increased dynamic knee valgus. Taken with previous findings, it is plausible that biomechanical factors play a role in therapeutic outcomes with foot orthoses, but only in those with more mobile feet.

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P1-D-44 Activity-dependent axonal hyperpolarization contributes to NMES-induced contraction fatigability

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BACKGROUND AND AIM: There are numerous benefits in using neuromuscular electrical stimulation (NMES) as a rehabilitation tool to improve the quality of life for those living with a neurological disease or motor-impairment. Unfortunately, these benefits are limited by rapid muscle contraction fatigability. Recently it has been suggested that activity-dependent hyperpolarization of motor axons under the stimulating electrodes contributes to this fatigability. After axons conduct trains of impulses they become less excitable (hyperpolarize) and the threshold current required to generate a propagating signal increases. The present study was undertaken to determine the magnitude and time course of activity-dependent axonal hyperpolarization during NMES delivered at three stimulation frequencies. METHODS: NMES was delivered at 20, 40, or 60 Hz to the common peroneal nerve to generate 480 contractions over 8 min, using 200 µs pulse widths and a 0.3 duty cycle (300 ms stimulation, 700 ms rest). Axonal excitability was measured as changes in the stimulation current required to produce a compound muscle action potential of ~30% of maximum, using the QTRAC threshold-tracking program. Axonal threshold current measurements were recorded using 200 µs pulses before and at one second intervals during the 8 min of NMES. NMES was delivered at an intensity larger than the threshold tracking pulse in order to ensure that only fatigued populations of axons were being tested. The rate of threshold change was calculated as the time between 10 to 90% change during the 8 min of NMES. RESULTS: Early results from one participant show that there was an increase in axonal threshold current during NMES, and this change was larger at higher frequencies. Threshold increased ~15% with 20 Hz stimulation, and ~25% with 40 and 60 Hz stimulation. Threshold change during fatigue occurred fastest with 60 Hz NMES (3.58 min) and at a slower rate with 20 and 40 Hz NMES (5.97 and 6.08 min, respectively). CONCLUSIONS: Activity-dependent axonal hyperpolarization plays a role in NMES-induced contraction fatigability and the magnitude and time course of threshold current change is frequency dependent. The magnitude of threshold current changes were larger and the time course was faster with higher NMES frequencies than with lower NMES frequencies. The results of these experiments provide insight into the biophysical changes that occur in axons during NMES. The results may be useful to improve the efficacy of NMES by minimizing contraction fatigability, particularly for those individuals that use it as a therapeutic tool, and thereby helping to improve their quality of life.

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P1-D-45 Performance and brain activation during slow speed and anatomical motion movie observation

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BACKGROUND AND AIM: A motion observation is one of the therapeutic options for rehabilitation of physical dysfunction to acquire a new motor skill. Previous studies indicated the motion observation facilitates motor learning of a novel motion and activates the motor cortex similar to performing an actual movement. For a systematic motion observation, it is necessary to produce the apparent movement imagery induced by the motor imagery, and it is important to choose the efficient viewing material. Motion movies: natural and slow speed; a first-person perspective anatomical and inversion view, are used for the viewing material of the motion observation. However, the best movie speed and the method of displaying the motion video for motion observation, influencing the motor cortex activations and the acquisition of motor skill, are currently unclear. The objective of this study was to assess the effect of motion observation from different directions, magnitude and distribution of elicited brain activation. METHODS: Seven right-handed healthy adults who had no experience of performance task joined our study and performed a multi-joint separate motor task considered of 45 trials by their dominant and non-dominant upper limbs. All trials were divided into three practice blocks (each consisted of 15 trials), and the number of successful trials was collected. Motion movie's speed was five times slower than the normal one, and the motion observation was performed under three different conditions: a first-person perspective anatomical view (model 1), inversion of model 1 (model 2) and non-motion (model 3). During the task, we measured the hemodynamic responses oxygenated hemoglobin around the primary motor cortex (M1) on both hemispheres using functional near-infrared spectroscopy (fNIRS). The successful trials and the hemodynamic responses for the three different models was compared. Results: Observing Model 1 showed a significant increase in the number of successful trials and hemodynamic responses in M1 areas on both their dominant and non-dominant upper limbs in compared with Model 2 and Model 3. CONCLUSION: This finding revealed that the slow motion movie's speed and a first-person perspective anatomical view is more effective during motor learning.

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P1-D-46 Evidence-based prescription of shoulder rehabilitation exercises as determined by EMG

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BACKGROUND Implementation of overhead activity, a key component of many professional sports, requires an effective and balanced activation of the shoulder girdle muscles, particularly during forceful external rotation (ER) motions. Study aimed to identify activation strategies of 16 shoulder girdle muscles/muscle segments during common shoulder ER exercises. METHOD Thirty healthy subjects were included in this study, and 16 shoulder girdle muscles/muscle segments were investigated (surface electrode: anterior, middle, and posterior deltoid; upper, middle, and lower trapezius; serratus anterior; teres major; upper and lower latissimus dorsi; and upper and lower pectoralis major; fine wire electrodes: supraspinatus, infraspinatus, subscapularis, and rhomboid major) using a telemetric electromyography (EMG) system. Five ER exercises (standing ER at 0° and 90° of abduction, with underarm towel roll, prone ER at 90° of abduction, side-lying ER with underarm towel) were studied. Exercise EMG amplitudes were normalized to EMG at maximum ER force in a standard position. Univariate analysis of variance and post hoc analysis applied on EMG activity of each muscle were used to assess the main effect of the exercise condition. RESULTS Muscular activity differed significantly among the ER exercises ($P < .05$ to $P < .001$). The greatest activation for anterior and middle deltoid, supraspinatus, upper trapezius, and serratus anterior occurred during standing ER at 90° of abduction; for posterior deltoid, middle trapezius, and rhomboid during side-lying ER with underarm towel; for lower trapezius, upper and lower latissimus dorsi, subscapularis, and teres major during prone ER at 90° of abduction; and for the clavicular and sternal part of the pectoralis major during standing ER with underarm towel. CONCLUSION Key glenohumeral and scapular muscles can be optimally activated during specific ER exercises, particularly in positions that stimulate athletic overhead motions.These results enable sports medicine professionals to target specific muscles during shoulder rehabilitation protocols while minimizing the effect of others, providing a foundation for optimal evidence-based exercise prescription. They also provide information for tailored muscle training and injury prevention in overhead sports.

P1-D-47 The effect of circumferential pressure on soleus muscle stiffness

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Circumferential pressure (CP) has been shown to decrease muscle activity in subjects without neuromuscular disorders and in individuals with spinal cord injury or cerebrovascular accidents. The mechanism for this decrease is unknown although it has been hypothesized to be spinal in origin. Spinal mechanisms of Ia reciprocal inhibition, pre-synaptic inhibition, nerve ischemia and nerve compression have all been studied and shown not to be involved. These results suggest CP's affect on the reflex arc may not be on the motoneuron (MN) reflex arc but rather on the mechanical properties of the muscle itself. Therefore, it is possible that the air splint simply "clamps" the muscle down, making it unable to stretch. Because the H-reflex is transmitted by Ia afferent fibers which monitor the velocity of a muscle's stretch, a decrease in stretch would result in a decrease in H-reflex amplitude. This decrease in a muscle's ability to stretch can be measured by looking at that change in force production during a quick stretching force applied to the muscle (muscle stiffness). The purpose of this study was to investigate the effects of CP applied to the leg on plantar flexor muscle stiffness. A positive result will explain the decrease in H-reflex amplitude found in previous neuromuscular studies. METHOD: Thirty-two healthy volunteers participated in this study. All subjects read and signed an informed consent form approved by the University's IRB. Subjects laid prone on a table with their knee flexed to 90º with the shank and foot secured. A pneumatic air splint was placed around the calf. Subjects then performed 3 maximum plantar flexion contractions. The mean force of these isometric contractions were converted to torque (maximum produced isometric torque-MPIT). The experiment began with the participant isometrically pressing against a stationary footplate and ramping up their contraction strength at 50NM / sec. until 60% of MPIT was reached. While the subject was maintaining their contraction level, a Kin-Com dynamometer randomly moved the foot in a dorsiflexion direction at 240º/ sec. stretching the posterior calf muscles. The muscle response to this stretch was recorded and saved. The process was repeated 10 times at 5 sec. intervals. This procedure was repeated 2 times; once before and again during CP. During the pressure phase of the experiment the pneumatic cuff was inflated manually to 50-55 mmHg. A one-way repeated measures ANOVA was used to compare stiffness before and during air splint inflation. RESULTS AND DISCUSSION: No statistically significant difference was found in plantar flexor stiffness between the two pressure levels. Therefore, CP does not affect muscle stiffness of the planarflexor muscle group. This suggests that the decrease in muscle activity (MA) observed in previous CP studies were not related CP's affect on muscle. Decrease MA must be due to some other mechanism.

P1-D-48 Effects on cervical spine kinematics following Ergo-Motor intervention: an integrated approach combining motor control training and ergonomics

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Background Work-related neck-shoulder disorders are highly prevalent in the workplace and outcomes of conservative interventions may be varied. With the contributing factors of problems associated with motor control and work-related physical stress, this study examined a new and integrated approach by combining the intensive motor control training and ergonomic intervention for management of people suffered from chronic neck-shoulder disorders. Methods 85 adults suffered from chronic neck-shoulder disorders were randomized into 2 intervention groups, namely the Ergo-Motor (EM) group and Conventional Physiotherapy (CO) group. Participants in CO group received a 12-week conventional treatment for pain relief and general mobilization exercises. EM group received a same period of intervention with individualized programme that integrated motor control training of the neck and shoulder region, advice and modifications of the workplace ergonomics. Cervical and scapular kinematics was examined during self-paced active neck movements test in all three movement planes using the three dimensional motion tracking system, before and after the intervention. The neck movements were performed with and without the setting of scapulae close to the optimal position. Three-way analysis of variance was used to compare the response of the cervical and scapular kinematics for comparisons 1) between CO and EM groups 2) with and without optimal scapular setting and 3) before and after the course of intervention. Results There was no significant difference of the cervical mobility before and after the intervention in both groups. Significant improvement of the cervical velocity and acceleration in all three movement planes was found in all participants when performing neck movement tests with and without the scapula position settings. EM group demonstrated a significantly greater improvement on cervical velocity and acceleration in flexion-extension direction compared to CO group (Figure 1). Significant decrease in the difference of scapular posterior tilting between trials with and without scapular position setting was found only in EM group before and after the 12-week intervention. Conclusions The innovative intervention approach which integrates the tailor-made training of motor control in the workplace resulted in superior improvement in the differential kinematics of the cervical spine during active neck movements compared to conventional group. The significant interaction effect found in the difference of the scapular positions between two scapular settings, before and after the course of intervention implies that modification of the motor control strategy in EM group in terms of the postural awareness and more optimal scapular position. Such change of the motor control pattern found in the neck-shoulder region in EM group may possibly contribute to a more sustainable improvement in work-related musculoskeletal symptoms in the long-term.

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P1-D-49 Validity of estimation of pelvic floor muscle activation through transperineal ultrasound imaging in women

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BACKGROUND AND AIM: Ultrasound imaging (USI) is becoming a popular means for evaluating muscle activation in rehabilitation settings. USI has been used to evaluate pelvic floor muscle (PFM) structure and function in women with urinary incontinence, pelvic pain, and pelvic organ prolapse. Changes in pelvic morphology seen during contraction, Valsalva and coughing tasks have been attributed to PFM contraction and relaxation. However, USI has not yet been validated as a tool to study PFM activation. The purpose of this study was to investigate the relationship between PFM activation, recorded using intravaginal surface electromyography (EMG), and changes in sagittal plane pelvic morphology measured using transperineal USI. METHODS: Eight healthy, nulliparous women without urogynaecological symptoms participated in the study. Each woman performed three repetitions of a PFM maximum voluntary contraction (MVC) while EMG data were recorded at 1000 Hz from both the left and right sides of the vaginal wall using differential suction electrodes, and pelvic morphology was imaged transperineally using a GE Voluson-i USI system using a 4.5-9Mz curvilinear 3D probe. To synchronize the USI with the EMG, a trigger pulse was used on a third EMG channel to mark the time at which the USI began. EMG data were rectified and smoothed using a fifth-order, 3Hz dual-pass low- pass filter and normalized to the peak of each trial. EMG data from the right and left side of the vaginal wall were averaged. USI data were processed through visual inspection. The levator plate length (LPL), the perpendicular distance of the bladder neck (BN) to the levator plate, the distance of the BN to the posterior aspect of the pubic symphysis (PS), and the distance of the urethra to the PS at the point where it passes through the levator plate were identified on each USI frame and motion profiles were computed across each trial. The motion profile data were interpolated to 1000Hz and normalized to the peak of motion of each morphological feature for each trial. The onset of EMG activation (using the averaged EMG from right and left sides) and onset of change in LPL, BN position, BN excursion and urethral excursion during each trial were then determined for each trial through visual inspection using a custom Matlab GUI. The cross correlation coefficients and the relative timing of PFM EMG activation onset were computed for each morphological feature. The relative timing of activation, and the correlation coefficients between PFM EMG and pelvic morphology were compared using one-way analysis of variance models (ANOVAs), and Tukey's pairwise comparisons ($\alpha=0.05$). RESULTS: In seven of eight participants, changes in pelvic morphology followed closely with PFM EMG activation (Figure 1a), yet in one woman (P2), the BN and urethral motion did not track well with PFM EMG activation although the LPL did (Figure 1b). All correlation coefficients between the PFM EMG signal and motion of the different pelvic morphological features were good (>0.90) and highly significant ($p<<0.001$), even those computed including P2. The

relative timing of onset of activation was highly variable and was not different between the PFM EMG and changes in morphology. The correlation between PFM EMG and LPL was significantly higher than the correlations between PFM EMG and BN and urethral motion (F=3.60, p=0.009). CONCLUSIONS: Using sagittal plane pelvic morphology, changes in LPL, BN position relative to the levator plate, and BN and urethral displacement relative to the PS are all highly correlated with PFM activation and can therefore be used to infer PFM activation. Because the BN and urethra are not directly attached to the PFMs their motion may be influenced by other factors, particularly intra-abdominal pressure. Changes in LPL are most closely associated with PFM contraction compared to measures of BN or urethral motion, the latter requiring cautious interpretation.

P1-D-50 System Identification of Two Degrees of Freedom EMG-Force at the Hand-Wrist Using Dynamic Models

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BACKGROUND: Commercial myoelectric hand-wrist prostheses use surface EMG from the residual forearm muscles to control movement, thereby realizing partial function. Traditional prostheses only control 1 degree of freedom (DoF) at a time, regulating the hand or wrist separately. This project studied the feasibility of controlling 2 DoFs--hand and wrist simultaneously. In addition, previous research studies required a large number of electrodes to extract 2-DoF EMG information, which is not practical for commercial prostheses. Our study explored the minimum number of electrodes required for hand-wrist control. METHODS: Ten able-bodied subjects finished the experiment, one of which was excluded due to erroneous EMG values. Sixteen bipolar EMG electrode-amplifiers were equally spaced in a transverse row around the proximal forearm. The hand was secured to load cells that measured 1-DoF hand open-close (Opn-Cls) force and 3-DoF wrist forces/moment. A screen located in front of the subject showed the load cell outputs and a computer-generated random moving target. Subjects used the load cell feedback signals to track the movement of the computer target. Initially, 1-DoF trials separately tested hand Opn-Cls or wrist extension-flexion (Ext-Flx), radial-ulnar deviation (Rad-Uln) or pronation-supination (Pro-Sup). Then, 2-DoF trials tested hand Opn-Cls coupled with one of the three wrist dimensions. Each different movement had four trials; two were used for training and two for testing (RMS error normalized in %MVC). Linear dynamic FIR models were fit using regularized least squares. Backward stepwise selection was used to reduce the number of selected electrodes from 16 down to 1. RESULTS: For 1-DoF models, ANOVA with Tukey post hoc tests showed that at least 2 electrodes were necessary, with no significant difference in error found with more electrodes. With 2 electrodes, the errors for Opn-Cls, Ext-Flx, Rad-Un and Pro-Sup

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were: 11.2±2.0%, 8.2±1.7%, 8.8±1.3% and 8.9±2.6 %MVC. Opn-Cls always exhibited higher error than the other three DoFs (P<1E-4), and Rad-Uln errors were significantly higher than Ext-Flx (P=1E-4). For 2-DoF models, 4 or 5 electrodes were required to obtain an error which was not significantly different from using more electrodes. With 4 electrodes, errors for Opn-Cls combined with one of Ext-Flx, Rad-Un or Pro-Sup were: 8.9±1.8%, 8.9±1.6% and 9.2±1.3 %MVC. Pair-wise sign tests between different motion combinations showed that there was no significant error difference (P>0.8 for all three paired comparisons). CONCLUSION: The results show that 2-DoF control demonstrated similar error levels when compared to 1-DoF control (which represents the current state of the art). Two-DoF prosthesis control with a small number of electrodes may be feasible. Further study including limb-loss subjects is warranted.

P1-D-51 In vivo characterization of muscle viscoelastic properties using shear wave elastography

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BACKGROUND AND AIM: The net force in a muscle can be generated by active and passive components that depend, respectively, on the contractile elements of muscle cells and the connective tissues within and surrounding them. These microscopic structures can each be affected by disease and injury, thus leading to altered muscle mechanics. Presently, there are no non-invasive techniques for quantifying the passive and active contributions to intrinsic muscle mechanics, as would be needed to identify the mechanisms of disease and injury or to track therapeutic interventions targeting them. Ultrasound-based shear wave elastography is a promising technology for characterizing muscle mechanics. Most previous applications have considered only the elastic properties of muscle. However, muscle is viscoelastic, and viscoelastic characterizations in other biological tissues have been used to link microscopic structure to macroscopic properties. The objective of this study was to determine if shear wave elastography could be used to separately characterize the active and passive forces generated within a muscle while considering the viscoelastic properties. METHODS: Ultrasound-based shear wave elastography data were collected from the biceps brachii muscle using a Supersonic Aixplorer system. Data were collected from 7 healthy adults. Biceps active force was regulated by voluntary activation at 0, 10, 20, and 30% of maximum voluntary contraction as measured using electromyography and elbow torque. Passive force was regulated by changing muscle length using elbow flexion angles of 80, 90, 135 and 180 degrees. Shear wave phase velocities were estimated from the ultrasound data over a range 0 - 800 Hz. A Voigt model was fit to the estimated phase velocities and compared between active and passive conditions. RESULTS: An analysis of the group results showed that muscle elasticity increases significantly with both active contraction ($p < 0.001$) and passive stretch ($p < 0.001$). In addition, the viscosity increases significantly ($p < 0.001$) as a function of activation level when the force is modulated by active contraction, but it shows little increase as a function of muscle length when the force is modulated by passive stretch. CONCLUSIONS: Our results agree with previous findings that shear wave elastography is sensitive to muscle force, and that the elastic components of muscle change with passive and active force generation. Our main contribution is demonstrating that viscosity is much more sensitive to actively generated muscle forces than to passively generated forces. This result is likely due to the microscopic structures transmitting force within a muscle, and how those structures are differentially stressed during active and passive loading. Future work will explore the mechanistic relationship between these structures and the macroscopic properties accessible with elastography.

P1-D-52 Reorganization of neuromuscular coordination when learning new cycling tasks

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BACKGROUND AND AIM: Cycling training in combination with biofeedback can be used to promote neural plasticity in subjects with neurological injury. Our principal aim was to test the effectiveness of a new and simple biofeedback technique, based on online visualisation of EMG activity, in modifying the neuromuscular coordination of lower limb. In order to measure the neuromuscular coordination, we used muscle synergies analysis, which has been demonstrated as a valid technique to describe most the variance of EMG of healthy and neurologically injured people during cycling. In particular, we were interested in investigating how the number and structure of muscle synergies and their activation coefficients will change when the subject is learning to modulate the timing of one specific muscle activity. METHODS: We included four healthy subjects in the experiment. The protocol consisted in three separate training sessions. In each session the subject was asked to change the peak of activation of one muscle, whose EMG envelope was extracted online and displayed visually at the end of each cycle, during four trials of 60 cycles each. The three training session were targeted to three different muscles, i.e. tibialis anterior (TA), gastrocnemius medialis (GM) and vastus lateralis (VL). We extracted muscle synergies and activation coefficients from eight lower limb muscles, and analyzed the differences between pre and post training session. RESULTS: Preliminary results showed that the biofeedback technique was effective in changing the timing of the target muscle. We also observed changes in the neuromuscular coordination, especially in the activation coefficients, whereas the muscle synergies were not visibly affected by the learning process. We also observed that the changes in the activity of

the target muscle induce effects on other muscles not belonging to the same synergies. Whether this comes from a neural or biomechanical coupling should be clarified. CONCLUSIONS: Online biofeedback on EMG during cycling demonstrated to be effective in modulating the neuromuscular control of cycling, and in particular in modifying the timing of muscle synergies while preserving a modular control. Future work will be devoted to clarify the mutual effects between the changes in the target muscle and the other muscle synergies. These results support the use of cycling in combination with biofeedback as a potential new technique to restore coordination in people affected by neurological injury.

P1-E-53 Changes in the respiratory and the stomatognathic system caused by idiopathic scoliosis

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AIM: Scoliosis produces deviations of the physiological curves in the frontal and sagittal planes, leading to spinal deformities, changes in the respiratory and ventilatory mechanics, and pathophysiological imbalance in the stomatognathic system. The present study aimed to analyze the changes in the respiratory and stomatognathic system caused by acute idiopathic scoliosis. METHODS: Twenty women, aged 18 to 30 years (23.80 ± 2.94 years) were divided into two groups: Scoliosis Group (n=10) with acute idiopathic scoliosis and Control Group (n=10) with healthy participants. The masticatory muscle activity and the muscle activity of the spine were evaluated by means of EMG. A manuvacuometer was used to measure the respiratory muscle strength to understand how the disorders caused by severe idiopathic scoliosis in the spinal system can affect the performance of both the stomatognathic and the respiratory system. EMG and respiratory muscle strength data were tabulated and submitted to statistical analysis (SPSS 21.0) using the Student's t test for independent samples, with a significance level of 5% and a 95% confidence interval. RESULTS: The significant statistical difference was found between both groups in conditions of rest for the right temporal muscle (p=0.02), clenching with parafilm for the right temporal muscle (p=0.03), chewing raisins for the masseter muscle (p=0.05), chewing peanuts for the masseter muscle (p=0.03), cervical flexion in neutral posture for the right sternocleidomastoid muscle (p=0.03), lumbar spine in extension for the multifidus muscle (p=0.04), maximal inspiratory and expiratory pressure (p=0.01). The results obtained showed that the convex side of the curve in severe idiopathic scoliosis has produced functional changes in the stomatognathic system, increasing the action potential of the masseter, temporal and sternocleidomastoid muscles. CONCLUSION: The results showed that the

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inspiratory and expiratory muscle strength was reduced by the influence of the action potential of the multifidus muscles that create rotational moment between vertebras. It can be concluded that acute idiopathic scoliosis interferes in the clinical conditions of mandibular rest, clenching with parafilm, chewing raisins and peanuts, cervical flexion in neutral, extension of the spine and respiratory muscle strength. ACKNOWLEDGEMENT: FAPESP (2013/22199-3)

P1-E-54 Functional analysis of the stomatognathic system in individuals with fibromyalgia syndrome

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AIM: Fibromyalgia syndrome is characterized by the presence of diffuse pain and chronic symptoms of morning stiffness, fatigue, sleep disorders and presence of tender points. The objective of this research was to analyze the effects of fibromyalgia syndrome in the performance of the masticatory muscles. METHODS: This study was previously approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of Sao Paulo. A sample of 69 women (40-65 years) Were divided in two groups: 34 women health (Control Group) and 35 women with fibromyalgia syndrome (fibromyalgia Group - FG). All Individuals were submitted to EMG test measured on masseter and temporal (right and left) muscles using the EMG-Br1 Myosystem®. These muscles were analyzed during usual mastication and postural movements like rest, protrusion, left and right laterality. The values were normalized by the value of the electromyographic signal of maximum dental clenching, harvested by four seconds. The electromyographic means were subjected to tabulated and statistical analysis using t test (SPSS version 21.0). RESULTS: The results observed in participants with fibromyalgia syndrome showed greater electromyographic activity in the clinical conditions of rest, left and right laterality and protrusion of the jaw for all analyzed muscles. During chewing of soft foods (raisins) and hard (peanuts) there were lower values of masticatory efficiency to the members of the group with fibromyalgia syndrome. CONCLUSION: Based on these results, we can conclude that the participants with fibromyalgia syndrome have compromising conditions of the stomatognathic system that may reflect the facial fatigue and occasional pain in the region of the face and neck, which can compromise the activity of chewing of the stomatognathic system.

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P1-E-55 Effects of regionally selective activation of trunk muscles on dimensions of upper and lower thoraxes during respiration

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BACKGROUND: Chest movements may be categorized into several patterns depended on the skeleton flexibility and trunk muscle activity (Fujihara et al., 2012). We are attempting how these categorized chest movements could be utilized as interventions for respiratory diseases. Here we investigate effects of regional activities of trunk muscles on upper and lower chest movements during respiration to understand the kinetic chain in chest upon selective activation of abdominal and back muscles. METHODS: Subjects were 12 healthy adults (24.0±2.4 yo). Using medical stimulator, mild electric stimuli were applied two ways: one simultaneously onto two regions of bilateral upper back and frontal abdominal muscle group (UAP stimulation) and the other onto two regions of bilateral upper chest and lower back muscle group (ULP stimulation). Using 3-D motion analysis system (ViconMX), chest movements were captured with markers on the midpoint of bilateral 3rd sternocostal joints (R3), xiphoid process (XP) and spinous processes of 4th (T4) and 10th thoracic vertebra (T10). Anteroposterior diameters (APDs) of upper thorax (R3-T4 distance) and lower thorax (XP-T10) were regarded as upper and lower thorax dimensions, and extents of expansions of upper and lower thoraxes were estimated during resting respiration for 1min (control) and test respiration with electrically stimulated muscles for stable 30 sec. Using gas analyzer, tidal volume (TV) was measured simultaneously along above measurements. Tested values were normalized as % of control (mean±s.d.). Paired t-test was used for statistical analyses. Ethics Committee of Bunkyo Gakuin University, approval 2015-0007. RESULTS: APDs of upper thorax, but not lower thorax, at expiratory and inspiratory levels were significantly bigger in UAP stimulation (100.3±0.7 and 100.4±0.8%, respectively) than ULP stimulation (99.9±0.6 and 99.9±0.5%). The extents of thorax expansion were not different between UAP and ULP stimulations. While, ULP stimulation elicited increased values of TV in 9 out of 12 subjects as compared with UAP stimulation, although the mean values were not significantly different. CONCLUSION: The results suggest that regional selective stimulations of trunk muscles produce different effects between upper and lower thorax dimensions. The selective stimulation of UAP was revealed as increases in upper thorax dimension at both expiratory and inspiratory levels, suggesting that UAP stimulation shifts the upper thorax to more inspired levels. Although insignificant in mean values, ULP stimulation seemed to increase in TV in many subjects. The main factor for this TV increase may be the decrease in thorax dimension at expiratory level, presumably leading to the efficient expiration. Though small effects in healthy subjects, UAP and ULP stimulations may be beneficial for patients with respiratory disorders, as expanding and shrinking thorax dimensions by region selective activation of trunk muscles.

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P1-E-56 Evaluation and analysis of respiratory muscle strength of patients with multiple sclerosis

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AIM: Multiple Sclerosis (MS) is a chronic, degenerative and autoimmune disease that affects the central nervous system, characterized by demyelination; and that its signs and symptoms vary by location of injury. Since it affects the motor pathways MS is associated with reduced muscle strength, including the respiratory muscles. The aim of this study was to evaluate through electromyography and manovacuometry the respiratory muscle strength in patients with MS. METHODS: A total of three patients diagnosed with MS and three health patients in the control group, all women aged 24 and 42 who underwent evaluations of maximal inspiratory and expiratory pressures (MIP and MEP) and electromyography of the right serratus muscles (MSD), right intercostal (MID), right sternocleidomastoid (ECOMD) and diaphragm (MD). RESULTS: Through the electromyographic evaluations and respiratory pressures found out the imbalance in the activation of muscle fibers with the occurrence of weakness of the muscles evaluated in patients with MS when compared with the control group. The patient 1 presented MIP: -50 cmH2O and MEP: 40cmH2O; patient 2 MIP: -60 cmH2O and MEP: 40cmH2O and patient 3 MIP: -40 cm H2O and MEP: 40cmH2O. Electromyographic evaluation during diaphragmatic expiration of MS patients showed: patient 1 MSD: 3.11 - MID: 2.10 - ECOMD: 16.42 - MD: 19.09; patient 2 MSD: 1.95 - MID: 2.63 - ECOMD: 6,90 - MD: 6.86 and patient 3 MSD: 2.33 - MID: 3.45 - ECOMD: 6.42 - MD: 13.57. And the control patients showed: patient 1 MSD: 12.62 - MID: 8.35 - ECOMD: 22.83 - MD: 63.33; patient 2 MSD: 17.41 - MID: 8.57 - ECOMD: 14.05 - MD: 69.68; and patient 3 MSD: 14.76 - MID: 4.48 - ECOMD: 17.78 - MD: 43.65. CONCLUSION: We conclude that MS patients have respiratory muscle weakness and respiratory physiotherapy is essential to improve and maintain muscle function, possibly leading to better performance in daily life activities and functionality of the same.

P1-E-57 Analysis of the chewing in women post-mastectomy - pilot study

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BACKGROUND AND AIM: Understanding the factors and disorders that cause changes in the stomatognathic system, especially the masticatory efficiency is of fundamental importance in the clinical setting and scientific. The aim of this study was to analyze the electromyographic activity of right temporal (RT), left temporal (LT), right masseter (RM), left masseter (LM), right sternocleidomastoideus (RS) and left sternocleidomastoideus (LS) muscles, while performing of habitual and non-habitual chewing cycles. METHODS: 10 women with natural dentition were divided into two groups: MG, mastectomy group (n = 5, mean age 48.00 ± 4.54 years) and CG, control group (n = 5, mean age 50.00 ± 5.42 years). The EMG activity was recorded during normal chewing cycles and unusual through electromyography TrignoTM Wireless Delsys EMG System. This research was approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo. The habitual chewing was analyzed during chewing peanuts and raisins and non-habitual through flavorless gum (Parafilm M®; Pechinery Plastic Packaging, Batavia, IL, USA). Each condition was examined for 10 seconds. The groups were matched by age subject to subject and body mass index. Data were normalized by teeth clenching in maximal voluntary contraction. The EMG values were tabulated and analyzed using SPSS 21.0 software (t student test; $p < 0.05$). RESULTS: Statistical analysis showed no significant difference ($p<0.05$) during habitual and non-habitual masticatory cycles among the groups, however notes increased muscle activity during mastication in MG. CONCLUSION: It can be seen with this study muscular hyperactivity of EMG by analysis of the chewing cycles, suggesting functional changes in the stomatognathic system in women undergoing mastectomy. ACKNOWLEDGEMENT: FAPESP and CNPq

P1-E-58 Length dependence of the shear elastic properties of the biceps brachii after stroke

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BACKGROUND AND AIM: Hypertonia post-stroke is a motor control disorder associated with poor patient outcome. The etiology of hypertonia is unclear; usually the increase in tone is attributed to enhanced stretch reflex responses, however, the potential role of non-neural mechanisms is relatively uninvestigated. Currently we are examining the hypothesis that altered intrinsic muscle elasticity plays a role in mediating clinical hypertonia. The goal of this project was to determine if the stroke affected muscle has altered elastic properties within the muscle's range of motion. To this end, muscle's elastic properties were non-invasively estimated in the biceps brachii using supersonic shear wave elastography (SWE). METHODS: SWE was used to estimate the elastic properties of hypertonic and contralateral biceps

brachii throughout a range of elbow flexion angles. The velocity of shear wave propagation is known to be related to the stiffness of a material, so shear wave velocity (SWV) was used as a proxy measurement for muscle stiffness. In 13 hemispheric stroke survivors, SWV was measured in the lateral muscle belly while concurrent EMG activity was monitored on the medial aspect of the muscle belly. Stroke survivors have difficulty relaxing their muscles, so elastograms were eliminated from the analysis if EMG amplitude exceeded a given threshold in the 2 second period prior to image capture. The exclusion threshold was set at 4 times the RMS of baseline EMG. SWV recordings were manually cropped to exclude any connective tissue borders in a region of interest; velocities within the cropped region were averaged to provide one representative SWV value per image. Within a subject, shear wave velocity readings were binned by elbow flexion angle (bin size: 10 degrees). RESULTS: For stroke-affected muscle, SWV increased with elbow flexion angle at joint angles between 100º and 160º. For the contralateral biceps, SWV increased with joint angle at all angles above 120º. At joint angles less than 150º, SWV on the affected side was greater in 15/32 cases. The mean difference in SWV (affected-contralateral) was 0.10±0.68 m/s. At joint angles greater than 150°, SWV on the affected side was greater in 9/12 cases. The mean difference in SWV was 0.40±0.57 m/s. In only 3/13 subjects did the SWV of the affected side exceed the SWV contralateral by 1 m/s or more in the range of motion (for reference, SWV at slack length was approximately 2 m/s). CONCLUSIONS: The magnitude of the differences in shear elastic properties is key to understanding the role of passive muscle mechanics in hypertonia. The magnitude of these differences was limited (<1 m/s) for 10/13 subjects, which may indicate that muscle mechanics are minimally altered for most subjects. However, differences in SWV were large (> 1m/s) in 3/13 subjects, which may indicate that altered muscle mechanics play a role in a mediating hypertonia in a small subpopulation of stroke survivors.

P1-E-59 Acute Intermittent Hypoxia Augments Upper Limb Neuromotor Function in Persons with Spinal Cord Injury

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BACKGROUND AND AIM: Most spinal cord injuries (SCIs) are incomplete, however spontaneous plasticity, mediated via the spared spinal pathways is slow and often insufficient to restore normal function. One unique approach to augment plasticity in spinal networks is via intermittent brief exposure to mild hypoxia i.e. brief bouts of low oxygen in the inspired air (also known as acute intermittent hypoxia or AIH). AIH induces rapid neuroplasticity, and has been shown to enhance volitional somatic motor output in the lower extremity within 60 minutes in persons with incomplete SCI. Whether AIH induced neuroplasticity is equally prevalent in spinal motor pathways regulating upper limb muscular function is not known.

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Accordingly, in ongoing studies our aim is to test the hypothesis that AIH will augment upper limb neuromotor function in humans. METHODS: In two sets of experiments, we quantified the effect of a single session of AIH (15, 90-second episodes of 10% oxygen) on voluntary elbow flexion and grip strength, respectively. First, we measured isometric flexion force at the elbow joint during maximal voluntary contraction (MVC) in three subjects (two able-bodied, and one incomplete cervical SCI). Muscle activity from the biceps brachii was also recorded using a 128 channel high density EMG grid. The root mean square (RMS) value for each channel was calculated to generate average RMS muscle activity maps. MVC was done before, immediately after, and 60-minutes post-AIH. Sham trials were done one week later in the same individuals with intermittent normoxia (room air). In the second set of experiments, we quantified the effect of AIH on grip strength in three individuals with chronic incomplete SCI. A baseline assessment of grip strength was made before administration of AIH, immediately after AIH, and then again at 60 minutes post-AIH using a hand-held dynamometer. RESULTS: We found that isometric MVC at the elbow joint increased by 45±5% in the two able bodied individuals, and by 30% in the SCI patient, at 60 minutes post AIH. This increase in strength correlated with increased activation of the biceps brachii muscle. Average RMS value increased from 198 ± 11uV to 350 ± 3uV, and from 351uV to 392uV following AIH, in the healthy subjects and SCI patient, respectively. Sham AIH resulted in no change. We also found that grip strength increased by 26±4% from baseline at 60 minutes post AIH in the three subjects with SCI. In comparison, there was a 5±3% change after normoxia in the same individuals with sham AIH. CONCLUSIONS: These preliminary observations demonstrate the potential for AIH to rapidly increase upper limb strength in persons with incomplete SCI. This modality could eventually be developed to induce spinal plasticity, either as an alternative to prevailing therapies, and as an adjunct to bolster the effectiveness of superimposed rehabilitative training in individuals with chronic incomplete SCI.

P1-E-60 Evaluation of the masticatory and cervical muscles in women post-mastectomy - pilot study

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BACKGROUND AND AIM: Breast cancer is considered the type that affects more women worldwide and the mastectomy is the surgical procedure for the treatment of tumor and adjacent tissues, and may cause in multiple functional and physical changes to the patients, such as lymphedema, limitation of range of motion, muscle and postural change. This study

aims to analyze the EMG activity of right temporal (RT), left temporal (LT), right masseter (RM), left masseter (LM), right sternocleidomastoideus (RS), left sternocleidomastoideus (LS) muscles, under different conditions postural jaw. METHODS: Were evaluated 10 women with natural dentition, divided into two groups: MG, mastectomy group (n = 5, mean age 48.00 ± 4.54 years) and CG, control group (n = 5, mean age 50.00 ± 5.42 years). This research was approved by the Ethics Committee. The registration of the EMG activity was performed through the electromyography TrignoTM Wireless EMG System Delsys, the postural condition of the jaw: protrusion (10s), right laterality (10s), left laterality (10s), mandibular rest (4s) and teeth clenching in maximal voluntary contraction with and without Parafilm M® (Pechinery Plastic Packaging, Batavia, IL, USA) (4s in each condition). The groups were matched subject to subject by age and body mass index. The data were normalized by teeth clenching in maximal voluntary contraction with Parafilm M®. The EMG values were tabulated and analyzed using SPSS 21.0 (t student test; P <0.05). RESULTS: There was no statistically significant difference (P <0.05) between the MG and CG, although it can be observed muscle hyperactivity in all conditions analyzed in MG. CONCLUSION: The authors concluded that this study suggests that women undergoing mastectomy show increased EMG activity of masticatory and cervical muscles, when compared at the healthy control group. ACKNOWLEDGEMENT: FAPESP and CNPq

P1-E-61 Effect of total knee arthroplasty on balancing capacity after sudden perturbation in patients with bilateral knee osteoarthritis

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The present study is a follow up analysis of dynamic balance of severe knee osteoarthritis (OA) patients who have undergone total knee arhtroplasty. The study introduces new parameters on sudden perturbation tests during bipedal stance of which characterization capabilities have been evaluated for future applications. 48 patients participated in the study (f:m, 34:14, 69,6±6,5 years, 81±17 kg, 165±10 cm), of which 32 suffered under sever bilateral OA, 5 of severe unilateral OA and 11 where part of the control group. Measurements were held directly before surgery and postoperatively in the second, sixth, twelfth and twenty-fourth week. Dynamic balance was assessed by PosturoMED© platform which consist of a rigid plate connected to a rigid frame by springs. The plate can move in plane and can be fixed on one end in the mediolateral direction. Release of the plate causes sudden perturbation in the person's balance standing on it. Subjects' compensation results a damped oscillation. Motion of the platform was recorded using a ZEBRIS CMS10 (ZEBRIS, Medizintechnik GmbH, Germany) computer-controlled, ultrasound-based motion analysis system. The resulting damped oscillation was characterized by Lehr's damping ratio (D),

orientation ratio (R) defined by the ratio of path lengths in anteroposterior (AP) and mediolateral (ML) directions, oscillation peak frequency (f), settling time (t), total path length (S), maximal velocity (v_max), and maximal accelerations (a_max). On the calculated parameters correlation analysis, between groups t-tests were applied. In the control group strong negative correlation was found between t and D (c=-0.7854) and strong correlation between t and S (c=0.8117). In the unilateral group these parameters show weaker correlation (t-D: c=-0.4565; t-S: c=0.73364). In bilateral group both correlations coefficients are under 0.15 in absolute terms. Neither of the parameters showed significant differences compared the preoperative results to the postoperatives, except for D in the 24th week in the unilateral group. Comparing the values to the control group D was significantly lower, S and t were significantly higher in both OA groups. Oscillation frequency in the bilateral group was significantly higher compared to the rest. Improvement of D in the unilateral group was observed after 6 months. Bilateral patients did not show postoperative improvement presumably due to the other affected OA knee. Correlation analysis suggested that D is the most prominence parameter to assess dynamic balancing in all groups, however at healthy adults and athletes t and S can be an alternative. R, v_max and a_max is better for characterizing the balancing method itself. The curves of v and a can indicate extra muscle movements, and conscious balancing, which can be utilized by athletes. R shows a good parameter to characterize balancing strategy; it might be useful for rehabilitation purposes and training.

P1-E-62 Spastic Semitendinosus Muscle of Cerebral Palsy Patients Tested Intra-operatively Does Get Affected by Epimuscular Myofascial Force Transmission but Shows no Abnormal Mechanics

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BACKGROUND AND AIM: Measuring the forces of knee flexor muscles with respect to knee angle (KA) intra-operatively [1] allows determining capacity of individual muscles of spastic cerebral palsy (CP) patients to affect joint mechanics. Recent separate testing showed no abnormal muscular mechanics (i.e., no narrow operational joint range of force exertion and no supreme active resistance capacity to stretch at low length) for spastic gracilis (GRA), semitendinosus (ST) and semimembranosus (SM), if the muscle was stimulated alone [e.g., 2]. However, co-activation of also an antagonist did change mechanics of spastic GRA [3]. We aimed at testing the following hypotheses: (1) inter-synergistic and antagonistic epimuscular myofascial force transmission (EMFT) [4-5] affects forces of spastic ST and (2) causes abnormal mechanics. METHODS: Isometric ST forces of children with CP (n=7, mean (SD)=8.7 years (5.1 years); GMFCS scores: level II-IV; 12 limbs tested) were measured intra-operatively

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as a function of KA from flexion (120°) to full extension (0°). Four conditions were tested. Spastic ST was activated: (I) alone, (II) simultaneously with its synergists GRA and SM, (III) simultaneously with its antagonist vastus lateralis (VL) and (IV) simultaneously with GRA, SM and VL together. In order to eliminate length history effects [1], the measurements were started in flexed knee position. Testing was completed for each condition before attaining a different knee angle (in 30° increments). Mean of ST forces of tested limbs per KA were assessed across conditions. RESULTS: ANOVA (factors: KA and condition) showed significant main effects on spastic ST forces, but no significant interaction. Condition I: ST forces attain (mean (SD)) the minimal value at KA=120° 3.1N (3.4N), peak value at KA=15° 84.3N (30.4N) and decrease at KA=0° to 78.0N (29.7N). Condition I vs. others: Post hoc tests showed that, co-activation of the synergistic and the antagonistic muscles caused spastic ST forces to increase substantially (the mean force increase equaled 30.8%, 34.5% and 34.4% for conditions II, III and IV, respectively). However, in none of the conditions spastic ST force-KA curves showed abnormal mechanics. CONCLUSIONS: Our first hypothesis is confirmed, but not the second. Therefore, the present study shows solid evidence for EMFT in human subjects and in conditions close to those in vivo. However, the findings indicate that mechanics of spastic ST remains normal also in conditions involving co-activity of synergistic and antagonistic muscles. This suggests strongly that spastic ST does not have the capacity to cause the pathological knee joint condition of CP patients. [1] Yucesoy C.A. et al. J Biomech, 2010 [2] Ates F. et al. Clin Biomech, 2013 [3] Ates F. et al. Clin Biomech, 2014 [4] Yucesoy C.A., Exerc Sport Sci R, 2010 [5] Yucesoy C.A & Huijing P.A., J Electromyogr Kinesiol, 2007 TUBITAK grant 113S293 is acknowledged.

P1-E-63 Influence of the ataxia on the masticatory efficiency

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BACKGROUND AND AIM: Ataxia is a neurological disorder of the cerebellar region which manifests itself in motor pathways causing loss of coordination of movements, disturbances in the control of body posture, changes in voice control and loss of articulation of words and dysphagia. This study evaluated the efficiency of masticatory through the ensemble average of the masticatory cycles in individuals with ataxia compared to healthy individuals. METHODS: 16 individuals aged 20 to 60 years of both genders were divided into two groups. GI ? Individuals with ataxia: 8 individuals were selected by a convenience sample. GII - Control: 8 healthy individuals were selected. The groups were matched subject to subject by

age and body mass index. They were submitted to electromyographic evaluation in right masseter (RM), left masseter (LM), right temporalis (RT) and left temporalis (LT) muscles in the clinical conditions of non-habitual chewing of flavorless gum (Parafilm M®; Pechinery Plastic Packaging, Batavia, IL, USA) and during habitual chewing of peanuts and raisins. The EMG analysis was performed using EMG-Br1 Myosystem®. The data were tabulated and entered into the statistical analysis (t Test) using SPSS version 22.0 for Windows. The Ethics Committee in Research of the School of Medicine of Ribeirão Preto, University of São Paulo, previously approved this study. RESULTS: The comparison of the efficiency of masticatory cycles for habitual and non-habitual chewing between the two groups didn?t show statistic difference ($p<0.05$) (Table 1). CONCLUSION: According to the results of this research it can be concluded that the masticatory efficiency was not affected by ataxia.
ACKNOWLEDGEMENT: FAPESP

P1-E-64 Characterization of Passive Muscle Viscoelastic Properties in Hemiplegic Stroke

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BACKGROUND AND AIM: We are investigating changes in passive mechanical properties of skeletal muscles in chronic stroke. Our objective was to quantify the altered viscoelastic characteristics of upper-extremity muscles post-stroke using the ultrasound shear wave elastography in a passive state. We hypothesized that post-stroke alterations in muscle properties include changes in tissue elastic as well as viscous properties. Furthermore, we also hypothesized that clinically observed hypertonia and increased muscle stiffness can be quantified using ultrasound shear wave velocity METHODS: We generated shear waves in biceps brachii muscles of stroke survivors and estimated the propagation speed using the supersonic imaging (SSI) ultrasound system. We collected ultrasound data from both arms of two hemiplegic chronic stroke survivors (modified Ashworth scale-2 for both participants) at three different elbow joint angles (90, 120, and 150 degrees). The electromyogram (EMG) was also recorded from the biceps muscles to ensure a passive condition during imaging. The ultrasound data were processed to estimate group and phase shear wave propagation velocities. The elastic properties were quantified by the group velocities while the viscous properties were estimated from the phase velocity data. In a purely elastic medium, the group and phase velocity values should be the same. The phase and group velocities are generally related to the local mechanical properties through mathematical models including, Maxwell, Kelvin-Voigt or the Zener model. RESULTS: We observed that the shear wave group velocities increased linearly with the elbow joint angles for both arms of tested stroke survivors ($p<0.001$). In terms of a comparison between stroke-affected and contralateral arm, we observed significantly higher shear wave group velocity values on the stroke-affected side in both stroke survivors (p<.0001). Furthermore, in terms of viscous properties, we found that stroke-affected muscles had significantly higher phase velocities in the whole estimated frequency range (0-800 Hz) in both stroke survivors (p<.001). CONCLUSIONS: These results suggest that key parameters of passive muscle mechanical properties, best described by the dynamic modulus (comprised of storage or elastic modulus and the loss or viscous modulus) has undergone alterations due to the upper motor neuron (stroke) lesion. In addition to abnormal neural mechanisms, which are manifested during muscular activation, the intrinsic muscular mechanisms, observed in a passive state, such as connective tissue infiltration and tissue fibrosis may play an equally important role in inducing weakness and disruption of contractile function. Therefore, the clinically observed increases in passive stiffness, in addition to reflex hyperexcitability, in stroke survivors may have resulted from local changes in the material properties of muscle and connective tissue.

P1-E-65 Older and young adults with chronic low back pain present increased back muscle fatigue

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AIM: The purpose of this study was to compare back muscle fatigue of younger and older participants with and without chronic low back pain (CLBP). METHODS: Twenty participants without and 20 with nonspecific CLBP participated in this study. Each group contained 10 younger (50% males; mean age: 31±6 yrs) and 10 older adults (50% males; age mean: 71±7.5 yrs). Two isometric fatigue protocols were presented randomly: (1) to maintain the unsupported trunk at the horizontal position while on a 45・ Roman chair for a minute, and (2) to maintain a 10% of body weight box close to the trunk in the upright position for a minute. Surface electromyography (EMG) signals from the back (multifidus and iliocostalis) and one hip (biceps femoris) muscles were recorded bilaterally, and the median frequency fatigue estimate from linear regression slopes of the EMG time-series was computed. RESULTS: There were no significant (P > 0.05) age effects, and group-by-age interaction in both isometric and functional fatigue tasks. However, the CLBP groups (both younger and old) displayed more back fatigue than people without CLBP in both fatigue protocols (P < 0.01; effect size varying of d = 0.17 to 0.32). CONCLUSION: This study was sensitive to discriminate that individuals with CLBP did present significantly more pronounced EMG back fatigue than people without CLBP, in both younger and older adults. These results have

significant clinical implications for low back pain rehabilitation programs with regard to endurance assessment in both younger and older.

P1-F-66 Motor unit firing pattern of vastus lateralis muscle and its association with the strength capacity in the elderly

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The decrease in muscle strength with aging cannot be explained solely by a decrease in muscle volume. This suggests that neural factors, i.e., motor unit activation, markedly contribute to the decline in the strength capacity of the elderly in addition to morphological changes. However, age-related changes in motor unit activation properties remain unclear for locomotor muscles, such as quadriceps muscles, although these muscles are preferentially atrophied with aging and play important roles in daily living activities. The present study aimed to investigate and compare detailed motor unit firing patterns for the quadriceps muscle during isometric contraction at low to middle force levels in the elderly and young. Also, we investigated the association between the motor unit firing pattern and strength capacity. Fourteen healthy elderly men (age: 71.1 ± 5.6 years) and 15 healthy young men (age: 20.6 ± 1.1 years) performed isometric ramp-up contraction from 0 to 70% of their maximal voluntary contractions (MVC) during knee extension. Multi-channel surface electromyograms were recorded from vastus lateralis muscle using a two-dimensional grid of 64 electrodes and decomposed with the convolution kernel compensation technique to extract individual motor units. Only motor units with PNR > 30 dB (corresponding to accuracy in motor unit firing identification > 90%) were used for further analysis, whereas all the other motor units were discarded. In this study, 131 and 114 motor units were considered for analysis for the elderly and young, respectively. Motor units were divided into three groups based on recruitment threshold: motor units recruited at <20% of MVC, 20-40% of MVC, and 40-60% of MVC. Firing rates of motor units recruited at <20% of MVC and 20-40% of MVC in the young were significantly higher (~%2B29.7%) than in the elderly ($p < 0.05$) at 50~60% of MVC force levels. There were significant differences in firing rates among motor unit groups with different recruitment thresholds at 40-60% of MVC force levels in the young ($p < 0.05$), but not in the elderly ($p > 0.05$). Firing rates of the motor units recruited at < 20% of MVC were significantly correlated with MVC force in the elderly ($r = 0.885$, $p < 0.0001$), but not in the young ($r = 0.127$, $p > 0.05$) at 60% of MVC force level. Lower motor unit firing rates and similar firing rates among motor units with different recruitment thresholds in the elderly suggest that motor unit firing patterns in the quadriceps muscle are modified by aging. Also, a strong correlation between the motor unit firing rate and strength

capacity in the elderly may help to explain the gap between decreases in muscle strength and muscle volume with aging by age-related changes in neural factors.

P1-F-67 Effect of posture on motor unit control investigated by decomposition techniques in adults after stroke

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Effect of posture on motor unit control investigated by decomposition techniques in adults after stroke Background and Aim Individuals after stroke often have several impairments such as muscle weakness, spasticity, and balance disorder. Especially, muscle weakness is an important problem related to motor function. Generally, muscle strength is determined by motor unit recruitment and firing rate. Previous studies have reported that the recruitment of high threshold motor units is selectively affected in adults with hemiplegia. However, to our knowledge, motor unit behavior in standing position has not been reported so far. Thus, we assessed the difference in motor unit recruitment and firing rates between standing and sitting positions by using decomposition techniques with surface electromyography(EMG). Methods Thirteen individuals with hemiplegia after stroke (57.1±10.7 years, Brunnstrom recovery stage III:1,IV:8,V:4) participated in this study. EMG signals were recorded on the vastus medialis using surface EMG (dEMG system, DELSYS Inc.). First, maximal isometric voluntary contractions (MVC) were recorded for 3 seconds in the sitting position. Second, isometric voluntary contractions at 25% MVC were performed in the sitting and standing position with visual feedback. In the standing position, participants were instructed to load the weight with the knee flexed at 45° to adapt to the amplitude at 25% MVC. The EMG data were analyzed using decomposition techniques to detect the number of motor unit (NMU) and the average of firing rate(AFR). Two-way repeated analyses of variance were performed to compare the difference between the paretic and non-paretic limbs or between the standing and sitting position. Results The NMU was significantly lower on the paretic side than on the non-paretic side; however, there were no significant differences between the positions. The AFR showed a significant interaction between the limbs and position. The AFR of the paretic side was significantly increased in the standing position, while no difference was observed in the sitting position. Conclusions The recruitment of motor units was limited on the paretic side as previously reported. Moreover, the firing rate of the paretic side differed according to change in the position despite remaining unchanged for the non-paretic side.

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P1-F-68 Evaluation of neuromuscular activation and force tracking accuracy during isometric sine-wave force exertion

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BACKGROUND AND AIM: The force accuracy during constant force exertion for the quadriceps femoris muscle (QF) is related to functional performance (Seynnes et al. 2005) and the force accuracy depends on type and level of contraction (Enoka et al. 2003). The sustained constant force level task has been used in previous studies because of its simple experimental design; however, it is unclear how the neuromuscular system modulates the motor units to control force accuracy against non-constant force level, such as sine-wave. The purpose of this study was to clarify neuromuscular activation and force accuracy of QF during isometric sine-wave force exertion. METHODS: Thirteen healthy men and women (23.0 ± 3.8 year-old) performed maximal voluntary contraction (MVC) during isometric knee extension. They performed force tracking task to match a given sine-wave force signal on a computer monitor. This sine-wave was expressed as a following formula: force = -2%MVC*sin (1/2πt) %2B 6%MVC, where t is time. As shown in this formula, one cycle of sine-wave force signal was consisted of 20 phases (P1 to P20): 1) P1 to P5 is 1st descending stage, 6%MVC to 4%MVC; 2) P6 to P10 is 1st ascending stage, 4%MVC to 6%MVC; 3) P11 to P15 is 2nd ascending stage, 6%MVC to 8%MVC; and 4) P16 to P20 is 2nd descending stage, 8%MVC to 6%MVC. Subjects performed 7.5 cycles (30-sec); one cycle of sine-wave was 4-sec. During the tasks, surface electromyogram (EMG) was recorded from vastus intermedius (VI), vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF). The root mean square (RMS) of EMG signals of each muscle was calculated in every 20 phases. We investigated force accuracy as fluctuation and it was also calculated as follows: (produced force - targeted sine-wave force) / targeted sine-wave force*100. The RMS of the individual muscles was normalized by the RMS of the MVC. We averaged RMS and force fluctuation from 2nd-cycle to 5th-cycle (i.e. 7 sec to 23 sec). Averaged force fluctuation and RMS was compared with eitherP5, i.e. the bottom of sine-wave (at 4%MVC), and P15, i.e. the top of sine-wave (at 8%MVC). RESULTS: Force fluctuation appeared to have inverse pattern to RMS of three vasti muscles. As a result of the cross-correlation analysis between force fluctuation and RMS of each muscle, there was approximately a half cycle lag, i.e. 8 or 10 phases. Force fluctuation at P1 and P10 to P20 was significantly lower than that of P5; however, force fluctuation at P2 to P8 and P18 was significantly higher than that of P15. The differences between phases were found at similar phases in RMS for VI, VL and VM, but not for RF. CONCLUSIONS: These results suggest that force accuracy during isometric sine-wave force exertion was contributed by change in recruitment and/or discharge rate of motor units in the vasti muscles, not RF.

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P1-F-69 Cutaneous post-synaptic potentials from the in vivo cat

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BACKGROUND AND AIM: The discharge of a spinal motoneuron and resultant force generation is regulated by the synaptic drive to and the intrinsic excitability of spinal motoneurons. Understanding these factors will provide insight into the generation of movement in healthy and pathological conditions. Current methods to investigate this activity in humans rely either on global indicators of motor output, such as surface EMG, or detailed analyses of single or pairs of motor units. Recent advances have allowed for the collection of the concurrent discharge of tens of motor unit spike trains. We have recently translated human derived motor unit approaches to the unparalyzed, unanaesthetised decerebrate cat model. Here we use this approach to describe the mixture of excitatory and inhibitory post synaptic potentials across the motor unit populations evoked through transient axonal stimulation. METHODS: During tonic motor activity of the left soleus muscle, either the left sural nerve or a cutaneous branch of the right superficial peroneal nerve are activated with single or brief trains (10 ms; 300 Hz) of electrical stimulation provided at ~1 Hz. Offline, the 64 channel soleus EMG signal is decomposed into corresponding motor unit discharge times using an automated decomposition algorithm. Each motor unit spike train is then triggered to the stimulation onset in order to quantify both the probability and instantaneous frequency of cutaneous evoked discharge, providing an estimate of the post-synaptic potential for each active motor unit. RESULTS: Peristimulus time histograms (PSTH) and peristimulus frequencygrams (PSF) for up to 20 concurrently active motor units consistently reveal excitatory post synaptic potentials evoked through sural stimulation, with PSF cumsum turning points located 50-70 ms post stimulation. These same motor units reveal stark variations in the preceding inhibition. A graded subpopulation of units will demonstrate an initial 10 ms pause in discharge at 25 ms followed at times by a decrease in discharge near 40 ms. A substantial minority of units demonstrate little of this inhibitory period and an earlier onset of excitation. CONCLUSIONS: Such responses vary across contralateral and ipsilateral pathways and are confirmed through concurrent fine wire motor unit recordings and similar PSF reconstructions from the same motor unit, tracked across many minutes. Such data suggest cutaneous evoked inhibition is unequally distributed across the soleus motor pool.

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P1-F-70 Motor unit synchronization during linear motor commands

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BACKGROUND AND AIM: The motor command underlying volitional activation of human motoneurons is unknown, though it is reasonable to assume the motor command is proportional to the resulting muscle force generation. Thus, during symmetrical ramp in torque generation, the net motor command is a symmetrical ramp of excitation. Though its assessment and interpretation remains controversial, the correlated and/or synchronous discharge of two or more spinal motoneurons may provide information regarding the synaptic drive common to both neurons. Because of the 1:1 relationship between the discharge of a spinal motoneuron and the contraction of its associated muscle fibers, we can record the greatly amplified discharge of muscle fiber to quantify the discharge of its associated spinal motoneuron in humans. Recent advances in high-density surface electromyography in combination with automated decomposition approaches can provide an accurate record of the discharge of tens of concurrently active motor units. METHODS: Kinetic and EMG data from four healthy humans were collected with the participants secured to an instrumented standing frame to quantify multiplaniar joint torque of the hip, knee, and ankle during isometric contractions from the right lower extremity. Following a series of maximal dorsiflexion contractions, motor unit discharge patterns were recorded from 64 channel surface arrays during linearly varying (2 deg/s) ramp contractions of the right tibialis anterior muscle to 20% maximal. Population estimates of motor unit synchronization were assess by constructing a composite crosscorrellogram across all unique pairs of motor unit discharges within a given a contraction for both the 10s ascending and 10 s descending phases. RESULTS: During each phase, significant zero-lag peaks in the crosscorrellogram were more evident during the descending phase of a ramp contraction. Our initial composite k' estimates are 1.31 ± 0.25 during the ascending phase and 1.45 ± 0.26 during the descending phase ($p<0.001$) across 31 contractions. Though mean k' values ranged considerably across subjects (1.07 to 1.62 during ascending ramps), values were tightly clustered within subjects with a mean CoV of 5.5 and 5.4% during ascending and descending ramps respectively. In three of these subjects, three separate 40s hold contractions were performed at 20% maximal. In all three individuals, composite k' values during hold contractions were tightly clustered and located midway between the low ascending phase and the high descending phase synchronization observed during ramp contractions. CONCLUSIONS: These preliminary data suggest motor unit synchronization is not static during linearly varying contractions in humans. If such data remain independent of the underlying motor unit discharge characteristics, it would support the hypothesis that the human motor command underlying a symmetric ramp contraction is asymmetric.

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P1-F-71 Motor axon excitability properties of the human gastrocnemius and soleus muscles

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BACKGROUND AND AIM: In animals, motoneuron electrical properties are related to the properties of the innervated muscles, but whether this is the case in humans is uncertain. This relationship can be determined indirectly by recording the excitability properties of motor axons in different muscles. Nerve excitability testing using threshold tracking techniques provides an indirect assessment of nodal and internodal ion channel properties and the resting membrane potential (1). An important feature is it is the only technique that can assess internodal properties in-vivo through the application of prolonged (ie.,300 ms) subthreshold polarizing currents. There are differences in axonal excitability along a single nerve in the human upper limb, even when the nerve is stimulated at one site and recordings are made from different muscles (2). Nerve excitability testing can also detect changes in axon properties in patients including those with cerebral palsy and other disorders (3). In this preliminary study of three healthy subjects, we tested the hypothesis that motor axon properties differ between the fast contracting and fatigable gastrocnemius and the slow contracting and fatigue-resistant soleus. METHODS: The tibial nerve was stimulated according to a standard (Trond + extended threshold electrotonus) protocol, and compound muscle action potentials (CMAP) were recorded over the gastrocnemius or soleus. RESULTS:The results indicate differences in membrane properties between axons that innervate the two muscles. Mean rheobase and the stimulus current required to produce 50% of the maximal CMAP were smaller in the gastrocnemius (3.2 mA and 4.9 mA) than the soleus (4.7 mA and 7 mA) axons. In addition, threshold increases elicited by the strongest subthreshold hyperpolarizing currents (TEhpeak, -100%) were smaller in the gastrocnemius (-358%) than the soleus (-434%) axons, an indication of greater activity of Ih, the depolarizing current that flows through the hyperpolarization-activated cyclic-nucleotide (HCN) channels. Pronounced differences in Ih is consistent with other studies which showed that Ih is an important determinant of differences in axon excitability between individuals and between motor and sensory fibers. CONCLUSIONS: These preliminary data indicate that gastrocnemius axons are more excitable and can accommodate hyperpolarizing currents better than soleus axons. These differences may be related to higher voluntary discharge rates in gastrocnemius compared to soleus motoneurons. 1. Bostock H et al. Threshold tracking techniques in the study of human peripheral nerve. Muscle & nerve. 1998;21(2):137-58. 2. Jankelowitz SK, Burke D. Axonal excitability in the forearm: normal data and differences along the median nerve. Clinical Neurophysiology 2009;120(1):167-73. 3. Klein CS, Zhou P, Marciniak C. Excitability properties of motor axons in adults with cerebral palsy. Front Hum Neurosci. 2015;9:329.

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P1-F-72 Evaluation of the neuromuscular fatigue in long-lasting cardiothoracic surgeries, using multi-channel EMG

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In the last decades it began to be common to evaluate the neuromuscular fatigue through different methods. One of the easiest ways of detection is through the lactate concentration, based in blood samples, however with this process it´s not possible to obtain real time values. So, for get real time values is possible to use electromyographic systems for the detection of the neuromuscular fatigue through measurements of myoelectric activity. This method is used in different areas like sports, health, rehabilitation, and others. In this work we investigate the muscular activation pattern of the shoulder and back, in surgeons during long-lasting cardiothoracic surgeries (approximately three to five hours), in order to detect the moment when the muscle starts to show some kind of fatigue. For that, we use a system of high density electromyography, allowing a better analysis of different regions of the muscle. For the multi-channel EMG analysis, different methods, namely Power Spectral Density (PSD), Short-term Fourier Transform (STFT), EMG signal Conduction Velocity (CV) and others, are tested to find the best method to detect neuromuscular fatigue. Results of applying the experimental protocol to a set of different surgeons are presented, along with the EMG analysis and comparison of the different methods to detect muscular fatigue.

P1-G-73 Feasibility study on effects of free bubble insole for walking

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AIM: Walking for health is currently popular, it should be discussed the types of insoles effect in terms of muscle activities. We adopt insoles composed of freely moving bubbles, expecting the enlargement of sensitivity for muscle fatigue and balance. METHODS: The measurement system was composed of the 16 channels wireless unit with the two-bar active electrodes (Myomonitor IV and DE-2.1, Delsys) for the SEMG signals. Signals were sampled at 2000 Hz at a 16-bit resolution using the attachment software (EMGWorks 3.5, Delsys). The target muscles and the locations of surface electrode were identified with both the muscle synergies at lower limbs and the spatiotemporal distribution pattern measured by 64 channels matrix (2D) electrode (ELSCH064R3S, OT Bioelecttronica). For free bubble insoles and barefoot, we ask participants to walk on the treadmill for 3 min with speed of 3 km/h: Note the quantities of bubble are 18g and 20g with the same bubble size. We focused on

muscles referring to the synergy weights over 0.5. The placement of a two-bar active electrode is determined where the highest change in RMS distribution pattern. RESULTS: From 8 healthy participants (22.6 ± 0.6) the time courses (TCs) of iEMG were estimated every ten strokes for total 100 strokes (Figure 1). Selected muscles among participants were Gas and Amm, TA and ERSP, BF, VL and Gmax based on synergies #1 ? 4, respectively. The time-varying behaviors were similar between barefoot and bubble with more quantity, but one with less quantity was different at ERSP, TA, and Gas. That is, for the first phase and over a task iEMG a little increased at ERSP and Amm and significantly decreased at the pair of TA and Gas and a little decreased at Gmax. DISCUSION: Effects of free bubble were explicit at the time-varying behavior of TCs. For one with less quantity muscle activities were reduced at TA and Gas and increased at ERSP. ERSP was reported to be highly activated in response to perturbations [1]. This might be caused by the instability at the sole of the foot. From the rectified envelop of SEMG at TA and Gas for a standard flexible shoe and a stability running shoe the peak amplitude increased compare to barefoot [2]. Although our results showed different tendencies, freely moving bubble might enlarge the sensitivity for balance stemmed from the effects of stochastic resonance [3]. [1] S. A. Chvatal and L. H. Ting, "Common muscle synergies for balance and walking," Front Comput Neurosci, vol. 7, p. 48, 2013. [2] L. A. Scott, G. S. Murley, and J. B. Wickham, "The influence of footwear on the electromyographic activity of selected lower limb muscles during walking," J Electromyogr Kinesiol, vol. 22, pp. 1010-6, Dec 2012. [3] M. Dettmer, A. Pourmoghaddam, B. C. Lee, and C. S. Layne, "Effects of aging and tactile stochastic resonance on postural performance and postural control in a sensory conflict task," Somatosens Mot Res, vol. 32, pp. 128-35, 2015.

P1-G-74 Mitigating the effect of wrist kinematics on pattern recognition control

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BACKGROUND AND AIM: Pattern recognition-based myoelectric control of upper limb prostheses has the potential to restore control of multiple degrees of freedom. Few studies, however, have evaluated the effectiveness of this control method in partial-hand prostheses. Recent studies have shown that wrist motion, which remains intact in many partial-hand amputees, degrades the ability of pattern recognition algorithms to correctly classify hand motions. In this study, we evaluate the effects of 1) non-linear and linear pattern recognition algorithms, 2) including wrist position information, and 3) training in multiple wrist positions on pattern recognition classification of 4 hand motion classes in different wrist positions. METHODS: Nine bipolar surface EMG electrodes were evenly spaced around the dominant forearm to record extrinsic hand muscle EMG. Four bipolar electrodes were placed on the

hand to record intrinsic hand muscle EMG. Two electrogoniometers were used to record wrist position. Six non-amputee subjects were prompted by a computer screen to perform 2 functional hand grasps, an open hand posture and a rest posture in 13 static wrist positions. Subjects held each hand posture for 3 seconds: this was repeated 6 times for each hand posture and wrist position combination. Offline classification error was calculated for a linear discriminant analysis classifier (LDA), quadratic discriminant analysis classifier (QDA), and a neural network with non-linear activation functions using data from all wrist positions. Classification error was evaluated using EMG data alone and using a combination of EMG data and wrist position information. An exhaustive search algorithm was used to determine classification error for all possible combinations of wrist positions. RESULTS: For EMG data alone, the neural network performed better than the QDA classifier ($p<0.05$) but there was no significant difference between the NN and LDA classifier ($p=0.49$). When both EMG data and wrist angle data were used to train the classifiers, the NN classifier performed significantly better than both the QDA classifier ($p<0.01$) and the LDA classifier ($p<0.01$). Adding wrist position data to the EMG data set improved only the neural network's performance. Training an LDA classifier with data from multiple wrist positions improved performance ($p<0.05$) but adding data from more than 6 wrist positions did not improve performance ($p=0.13$). DISCUSSION: Wrist position information provides little additional information for distinguishing hand postures though a neural network is able to utilize the wrist position information and improve performance. Our results also indicate that training a classifier in more than six wrist positions has no additional benefit which can greatly reduce the time-consuming and fatiguing process of performing grasps in multiple wrist positions.

P1-G-75 Towards the restoration of hand function using fully wireless cortically-controlled functional electrical stimulation

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Approximately one-third of spinal cord injury (SCI) patients lose hand function. Brain-machine interfaces (BMIs) provide a means to restore this function. We have previously shown the ability to restore voluntary hand function in monkeys during paralysis induced by peripheral nerve block. We used signals recorded from the hand area of the primary motor cortex (M1) to predict patterns of intended muscle activity and to control functional electrical stimulation (FES) of the paralyzed muscles. As in virtually all BMI experiments, these were performed intermittently in two hour-long sessions in the lab, with the monkey entirely normal between sessions. Here we present our work to develop a wireless cortically-controlled FES neuroprosthesis intended for continuous use. Our final objective is to demonstrate the feasibility of restoring hand use for month-long periods of time, permitting

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the monkey to use the neuroprosthesis on demand in its cage as well as in the lab. To extend our model of acute SCI, we have developed a long-term reversible peripheral nerve block using a subdermal infusion pump. The pump delivers tetrodotoxin (TTX), a sodium-channel blocking agent, to a silicone cuff wrapped around any of the three main nerves innervating the forearm and hand muscles. The neuroprosthesis itself uses a full-bandwidth transmitter (Blackrock Microsystems) to stream data from a 96-channel microelectrode array in M1. These data are used to predict intended EMGs, which are converted into stimulation commands sent wirelessly to a 16-channel stimulator (Ripple) stored in a backpack worn by the monkey. This control loop runs every 50 ms, and serves to evoke the voluntary muscle contractions the monkey is otherwise unable to generate. To demonstrate the feasibility of this neuroprosthesis, we performed experiments in rats and monkeys to determine combinations of flow rate and concentration that gave a continuous motor deficit using the subdermal pump. In the monkey, these were 2 ul/h and 250 ug/ml, respectively. The block was successfully reversed after one month in the rat and two weeks in the monkey. We next performed a series of short-term, wireless tests in the lab, restoring the monkey's ability to grasp objects, control grip force, and acquire targets in a 2D center-out wrist task. We are beginning to test this neuroprosthesis while the monkey is in its cage, to restore hand function for activities of daily living, such as foraging, feeding, or playing with enrichment toys. For these experiments, we will build neuron-to-EMG decoders using datasets recorded wirelessly in the cage, comprising a much broader set of behaviors than can be obtained in the laboratory. We anticipate that these decoders will allow more accurate EMG predictions and improve FES performance. These experiments will offer an unprecedented opportunity to explore the monkey's behavioral adaptation to the neuroprosthesis, and the underlying neural changes driving the adaptation.

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DAY 2, THURSDAY JULY 7

P2-A-1 A Systematic Analysis of the Relationship between Fine Wire and Surface Electromyography Onset Detection with and without the Teager Kaiser Energy Operator

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BACKGROUND AND AIM: Muscle onset timing using EMG is a critical measure used to examine temporal relationships between external or internal biomechanical and physiological events (e.g. gait cycle or agonist/antagonist co-activation). Both surface EMG (sEMG) and fine wire EMG (fwEMG) are used to determine EMG onset but the congruency between these two methodologies is not well-defined. Various EMG filtering techniques also exist that may influence this congruency and decrease the generalizability of study outcomes. Preconditioning the sEMG signal with the Teager Kaiser Energy Operator (TKEO) has been shown to improve sEMG onset accuracy in isolation. It is unknown how TKEO preconditioning affects the relationship between fwEMG and sEMG onset detection. The aim is to characterize the relationship between sEMG and fwEMG muscle onset determination using an iterative examination of the standard linear envelope with and without TKEO preconditioning in simple (short head biceps brachii) and complex (vastus lateralis) muscles. METHODS: Eighteen participants (ages 22 - 54 years) were instrumented with fine wire and surface EMG electrodes on the short head of the biceps brachii and on the vastus lateralis. Participants separately performed three elbow flexions and knee extensions with a 2.3 kg mass fixed distally at the wrist or ankle. Surface and fine wire EMG data were collected simultaneously from within the same region of the muscle. The EMG onset was then quantified with systematically varying linear envelope algorithms of differing low-pass filter types (2 Hz - 50 Hz) and detection thresholds (1 - 3 standard deviations in signal amplitude). This analysis was then repeated after EMG signal preconditioning with the TKEO. Pearson correlation coefficients were calculated between sEMG and fwEMG onset detection for all algorithms. RESULTS: Correlation ranges for the linear envelope method were -0.09 - 0.72 and 0.15 - 0.81 for the biceps brachii and vastus lateralis, respectively. The TKEO preconditioning resulted in ranges of -0.05 - 0.39 and 0.14 - 0.83 for the biceps brachii and vastus lateralis, respectively. The highest linear envelope correlation for the biceps brachii was 0.72 with a 25 Hz cutoff frequency and 3 SD threshold and 0.39 at 18 Hz and 3 SD with TKEO preconditioning. The highest linear envelope correlation for the vastus lateralis was 0.81 at 40 Hz and 3 SD threshold and 0.83 at 35 Hz and 2 SD with TKEO. CONCLUSIONS: The results suggest there is high variability in onset detection between algorithms. TKEO preconditioning increased the discrepancy between onset of surface and fine wire EMG in

the biceps brachii and therefore might not be appropriate. Muscle onset detection in simple muscles may benefit from using the linear envelope with a high cutoff frequency and a 3 SD threshold while more complex muscles may be improved by TKEO preconditioning with a high cutoff frequency and a 2 SD threshold.

P2-A-2 Continuous frequency change of SEMG for a transition period between knee extension and knee flexion during pedaling

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BACKGROUND AND AIM: The aim of this study was to investigate muscle?s energy pattern and spectral properties of lower limb muscle at a transition period between the knee extension and the knee flexion during pedaling movement. Although pedaling movement is a simple dynamic motion which adjusts a physiological function to a mechanical property of crank, the EMG activity on the lower limb muscles is not simple (Hug and Dorel, 2009). METHODS: The characteristics of muscle activity for ten competitive cyclists and eight non-cyclists were compared by using two wavelet transforms of SEMG signals from the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius medialis (GM). Firstly, the time-frequency map was made by Morlet wavelet analysis to estimate continuous frequency shift of muscle activity. Secondly, to investigate these muscle activities quantitatively, the SEMG signals were subjected to Daubechies-4 wavelet transformation, and mean wavelet coefficients of knee extension phase were compared with the mean coefficients of knee flexion phase in each wavelet level (i.e., j = 1: 250-500 Hz, j = 2: 125-250 Hz, j = 3: 62.5-125 Hz, j = 4: 31.25-62.5 Hz, and j = 5: 15.625-31.25 Hz, respectively). RESULTS: The SEMGs of RF and TA activated during the transition period from knee flexion phase to knee extension phase, and the SEMGs of BF and GM activated during the period of task shift from knee extension phase to knee flexion phase. According to the Morlet wavelet analysis, the peak frequency of SEMG of GM shifted to the higher frequency band during the task shift (Fig.1). For the knee flexion phase, the mean energy of wavelet levels of 2 (125-250 Hz) was significantly larger than that of the knee extension phase for the competitive cyclist group. Though, the frequency bands of muscle activities of RF, BF, and TA were not significant difference between knee flexion phase and knee extension phase for both subject groups. CONCLUSIONS: These results suggested that the muscle coordination, the motor unit (MU) firing frequency, and the firing fiber type of GM is changed with the different characteristics between the knee extension phase and the knee flexion phase in the competitive cyclist. The value of mean wavelet coefficient for SEMG signal of GM may be useful index for estimation of kinesiological motor skills relation to pedaling movement.

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P2-A-3 An Investigation of the Surface Electromyography-to-Force Relationship During Fatiguing Static Elbow Flexion

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BACKGROUND AND AIM: Extreme high pass (HP) filtering techniques, that eliminate up to 99% of raw surface electromyography (sEMG) signal power, significantly improve sEMG based estimates of the rested biceps brachii muscle force [1]. However, as fatigue progresses, sEMG becomes a less accurate means to estimate force, as more effort is needed for a given tension. The purpose of the current study was to explore the potential benefits of extreme HP filtering of sEMG to estimate biceps muscle force during fatiguing isometric flexion of the elbow. METHODS: Fifteen male participants were studied as they completed a series of rested, then fatigued, isometric biceps contractions on a Biodex while following a real-time moment-tracing template at varying intensities between 20% and 100% of their rested maximal voluntary contraction (20% intervals, n=5). sEMG of the biceps brachii was processed with 2 sets of data: 1) rested, 2) whole trial (rested + fatigued data). sEMG was processed using different HP cutoff frequencies (20 to 440 Hz in intervals of 30 Hz, n=15), and each HP cutoff was filtered with six different orders (1 to 6, in intervals of 1, n=6). RESULTS: The results indicate that there was no statistical significant main or interaction effects for either the rested or whole trial data when using the Greenhouse-Geisser correction. As fatigue progressed, extreme HP filtering did not appear to have the same benefit as during rested force prediction. CONCLUSIONS: Although no statistical significance was found with either data set, the data suggest that, for the purpose of force prediction, using a HP cutoff of either 260 or 290 Hz will tend to lower the RMS percent error, challenging the conventional filtering method of 20-500 Hz when estimating muscle force, even under fatigued conditions. References: [1] Potvin, J. R., and Brown, S.H.M., (2004). Less is more: high pass filtering, to remove up to 99% of the surface EMG signal power, improves EMG-based biceps brachii muscle force estimates. Journal of Electromyography and Kinesiology, 14(3), p.389-99.

P2-A-4 Wearable wireless multichannel sEMG acquisition system

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BACKGROUND AND AIM: This work describes a multichannel, wireless and compact 32 channels EMG acquisition system. The system architecture includes: (1) a transmitting unit managing up to 32 monopolar EMG signals sampled at 2048 Hz with 16 bit resolution; (2) a

mobile device (notebook, tablet or smartphone) that receives wirelessly the sampled signals. The transmitter and the receiver can be connected either via a direct link (point-to-point connection) or through a router. The latter type of connection can be useful in applications which need the connection of additional wireless modules (e.g. auxiliary channels) to the system. METHODS: The Intan RHD2132 front-end was chosen in order to minimize the size and encumbrance of the system. The RHD2132 chip is a complete, low-power and ultra-compact (size 9x9 mm) bio-signal acquisition system, which integrate 32 analog front-ends with programmable gain and bandwidth, an analog multiplexer, a 16 bit resolution A/D converter and a SPI communication interface. To achieve the high data throughput required for the wireless link (1 Mbps) and to connect the system to mobile devices without an ad-hoc receiver, the Texas Instruments CC3200 system on chip wireless MCU has been selected. A real-time operative system was used and two different parallel tasks (sampling and transmission) were implemented. The semaphores technique has been used in order to avoid conflicts between the two tasks. The software for the acquisition and online visualization of the EMG signals was developed using the multi-platform Qt libraries (Android, Windows, Linux and MAC). RESULTS: The Intan RHD2132 front-end has been tested using the Intan evaluation board. The relatively low input impedance of the chip does not preclude the possibility to acquire sEMG signals with low 50Hz interference (RMS<20 µV) within a 50Hz controlled field (80 V/m) when the system is battery powered. The performance of the selected Wi-Fi module was tested through a virtual sinusoidal signal generated into the MCU and transmitted to the PC and multiplexed over 32 channels. This setup was necessary to precisely control, off-line, the correspondence between the transmitted and the received signal and, then, check for and count the number of lost data packets. The resulting data throughput of the wireless link was 5.5 Mbps, allowing the transmission of up to 170 EMG signals sampled at 2ksps with 16 bit resolution. CONCLUSIONS: The tests performed on the components selected for the development of the wearable wireless multi-channel sEMG acquisition system showed good performances compatible with the system requirements. The nest steps will be the integration of the components into a single device. FIGURE: Concept of the wearable wireless multi-channel sEMG acquisition system

P2-A-5 Geometry-related variations in CMAP distribution over the soleus: a simulation study

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BACKGROUND AND AIM: We recently demonstrated that the amplitude distribution of H-reflex over the soleus (SOL) is spatially localized over a skin region corresponding to the Achilles tendon [1]. The complex architecture of this muscle was regarded as one potential

reason for this non-uniform EMG distribution. In SOL, the relative position and orientation between fibers and electrodes changes for different skin locations. Electrodes covering the muscle central portion (i.e., the Achilles tendon) are located in a plane oblique to SOL fibers, which are in-depth pinnate. Electrodes covering the medial/lateral regions, on the other hand, are positioned in a plane parallel to that where fibers reside. In this portion, however, fascicles are oriented in the anterior-posterior direction and therefore misaligned with electrode pairs aligned to the proximal-distal axis. In healthy subjects, this misalignment is variable in a range of 40-70deg. In this study we used simulated signals to quantify the geometry-related variations in EMG amplitude associated to different SOL regions. METHODS: A three-layer volume conductor model [2] was used to simulate compound muscle action potentials (CMAP) sampled from two muscle geometries reproducing the central and medial/lateral SOL regions. The simulated pinnation angle in the central portion was 25deg. Ten misalignment angles (from 0 to 90deg) were considered to simulate potentials detected from the medial/lateral SOL. Monopolar EMGs were simulated as detected by two electrodes with 10 mm IED and then differentiated to obtain single-differential signals. RMS amplitude was considered to quantify changes in monopolar and single-differential CMAP associated with different electrode-fiber arrangements. RESULTS: The RMS of monopolar CMAPs simulated in the SOL medial/lateral region was roughly 70% of that observed for potentials simulated at the muscle central region. Being monopolar derivation an isotropic montage, such difference between detection sites did not depend on the misalignment angle between electrodes and fibers simulated in the muscle medial/lateral portion. For single-differential CMAP, the RMS in the medial/lateral region decreased with the misalignment angle. RMS estimates were progressively smaller than those obtained for the central portion as the misalignment angle exceeded 30deg, with reduction of about 60% for a misalignment angle of 70deg. CONCLUSIONS: These findings confirm the experimental observations of larger H reflexes over the Achilles tendon in both monopolar and single differential derivations and suggest that the complex architecture of SOL is a key determinant of the non-uniform distribution of H reflex over its surface. The presented results have major implications for electrode positioning in applied studies aimed at eliciting CMAP responses in SOL. [1] Botter A. et al. Conf Proc IEEE Eng Med Biol Soc. (2015); 3460-3463. [2] Mesin L. et al. J Biomech. (2011); 1096-1103.

P2-A-6 Spike shape analysis of mechanomyogram during linear torque decrement in fresh and fatigued muscle

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AIM: Spike shape analysis (SSA) is a promising method to analyse electromechanical signals detectable from skeletal muscle surface during voluntary contraction. Both electromyogram and surface mechanomyogram (MMG) can be considered as interferential signals where the motor unit (MU) action potentials and the related transverse twitches of the recruited motor units (MU)are summated, respectively. On these bases SSA can be considered as a tool to study motor control strategies during muscle activation and deactivation. SSA has not been applied in the analysis of non-stationary MMG signal. The aim of the present study was to verify if the changes of MMG SSA parameters during controlled force reduction may provide information about MU deactivation strategy during torque decrement, and its possible changes with fatigue. METHODS: The MMG of the biceps brachii muscle was collected from eleven untrained male participants (mean ± SD for age 22.1 ± 0.9 years, body mass 72.6 ± 8.8 kg, height 181.8 ± 5.6 cm) during static down going ramp contractions (90-0% of the maximal voluntary contraction, MVC) under non-fatigued (DGR) and fatigued (FDGR) settings. The SSA parameters such as mean spike amplitude (MSA), mean spike frequency (MSF), mean spike slope (MSS), mean spike duration (MSD) and mean number peak per spike (MNPPS) were calculated simultaneously on 1 s MMG windows centred on each 10% MVC step for both settings (DGR and FDGR). Fatigue was obtained by the repetition of 6 s long 50% MVC efforts (3 s of rest in between) since the target force was not maintained for the whole requested period. RESULTS: DGR: the SSA parameters decreased from 90 to 10% MVC. At 70% MVC MSA and MSF presented about 40 and 9% of the total delta in 90-10% MVC range. FDGR: the dynamics of SSA parameters decrease with %MVC less steep than during DGR and the differences in the absolute values were significant up to 40% MVC. MNPPS were never statistically different in the two conditions.

P2-A-7 A closed-loop neuromuscular simulation can provide insights into the origins and task-dependencies of force fluctuations.

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BACKGROUND AND AIM: Human voluntary motor control naturally includes oscillations in neural activity and mechanical output. Oscillations in specific frequency bands have become a central tool to understand healthy and pathologic motor control. However, the origin of these oscillations, whether neural, muscular, mechanical, or combination thereof, is intensely debated. This is partially because our understanding of how oscillation amplitude/frequency are modulated by different neural and mechanical factors, even for isometric forces, is limited. Therefore, we used a computational model of afferented musculotendons to investigate whether and how tremulous oscillations can emerge naturally from fundamental neuromuscular interactions during static and dynamic isometric contractions. METHODS:Our simulations combined previously validated models of musculotendon dynamics, muscle spindles, and Golgi tendon organs, and can be driven in a feedforward or feedback manner. Modulation of force oscillations was tested with both the model and human subjects in various conditions such as dynamic isometric contraction and different fascicle lengths. RESULTS: We found that realistic amplitude modulation of force oscillations emerged naturally in the appropriate phases of dynamic isometric force production. Furthermore, tuning reflex gains affected the phase-dependent amplitude of force oscillations, and modulating force oscillations compatible with those seen in human studies. Lastly, modeling static isometric contractions also matched the dependence of physiological tremor (5-15Hz) amplitude on muscle fascicle length and choice of muscle observed in human subjects. These results suggest that force oscillations between 1 and 15Hz can be well-explained as a consequence of coupling between the muscle-tendon dynamics and spinal reflex activity, even in the absence of oscillatory central drive. Also, these results speak to the asymmetry in stretch reflex response between upper extremity extensor and flexor muscles. CONCLUSIONS: We conclude that straightforward closed-loop simulations of afferented muscle-tendon suffice to replicate oscillations in muscle force. Thus, they critically enable us to disambiguate the neural and mechanical sources of force fluctuations, and explain their context-dependent interactions.

P2-A-8 Evaluation of external anal sphincter innervation asymmetry in obstetrics

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Recent studies suggest that functional asymmetry of pelvic floor innervation exists in healthy subjects, and it is strongly associated with postpartum incontinence when the trauma occurs on the dominant side of innervation. Episiotomy is the most common cause of perineal trauma during delivery, and the surgical incision is usually performed on the mediolateral right side episiotomy. Surface electromyography (sEMG) in obstetrics is a novel method for detecting the innervation zones (IZ) of external anal sphincter (EAS). The aim of this study is to locate the IZs of EAS by the means of sEMG, and to analyse their distribution, in order to evaluate the effect of episiotomy on the external anal sphincter muscle activity. In this prospective observational type study, 225 pregnant primiparous women (age 28.4 ± 4.1 years) were involved and EMG was performed to detect the distribution of IZs and amplitude of EMG signals of EAS. The EMG measurements were performed two times: during the 2nd trimester of pregnancy and 6 weeks after delivery, in order to recognize any changes in the innervation after delivery. EMG signals were detected by a cylindrical probe with 16

electrodes and acquired with a multichannel amplifier (OT Bioelettronica, Turin, Italy). IZ distribution and signal amplitude were detected before and after delivery. The women were divided in two groups according to the EAS innervation asymmetry: left or right dominantly innervated. The changes of signal amplitude were analysed in subgroups according to the delivery mode (no damage, spontaneous lacerations, caesarean sections and right side episiotomies). Out of the 225 women analysed before delivery 149 women returned after delivery and were used for further analysis: (56) (38%) of them had episiotomy on the right side, (44) (30%) had spontaneous lacerations, (20) (13%) had no damage, and (29) (19%) had Caesarean section. The innervation was observed to be heterogeneous with a tendency of asymmetry predominant on the right side 138 (61%) compared to the 87 women (39%) innervated on the left side. None of the women had any sphincter damage before pregnancy or wound complications after delivery. No significant changes in EMG amplitude were observed in women who had caesarean section or delivery with no damage. While a reduction of amplitude was observed in case of spontaneous lacerations or episiotomy. In particular in case of episiotomy, the women with innervation on the right side had a stronger reduction of EMG amplitude after delivery compared to the women with innervation on the left side, suggesting that choosing the right side of episiotomy could have limited the amplitude changes. Superficial electromyography showed to be a promising method for detecting innervation zones before and after pelvic floor surgery, to avoid iatrogenic damage of pelvic floor innervation.

P2-B-9 The Effects of Fatigue in Backward Skating in Ice Hockey

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BACKGROUND AND AIM: A typical hockey shift on the ice lasts between 30 to 80 seconds, and physiological fatigue may affect a skater's skating performance. Bracko, Fellingham, Hall, Fisher, and Cryer (1998) found that an average player spends only 4.6% of a 60 second shift in high intensity skating. Hence, this indicates that the aerobic system also contributes with there being large amounts of low and medium intensity skating. Hagg, Wu and Gervais (2007) evaluated the effects of fatigue in the lower extremities in female ice hockey players and found significantly less ankle flexion in forward skating when players were fatigued. However, how fatigue affects backward skating performance remains unaddressed. Backward skating is particularly an important skill for defense positions in ice hockey because defensive players play close to 50% of the game compared to forwards who play approximately 35% of the game (Twist & Rhodes, 1993). Hence, defensive players are at greater risk for injury because of their increased ice time. Therefore, the purpose of this study was to examine the effects of physiological fatigue in backward ice hockey skating. METHODS: After providing

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University-approved informed consent, five male collegiate ice hockey players participated in the study. Each player was fitted with joint reflective markers at the shoulder, hip, knee, ankle and toe. Players completed five continuous repetitions of backward and forward skating between the goal lines at their highest intensity. The duration of this skating time was approximately 90 seconds, sufficient to promote anaerobic fatigue. A JVC video camera captured their sagittal view of skating motion at 60 Hz in conjunction with a 650W artificial light. A standard two-dimensional kinematic analysis was conducted with the Ariel Performance Analysis System to examine the trunk, hip, knee and ankle angles at the beginning and the end of backward skating. RESULTS: A paired-sample t-test ($\alpha = 0.05$) indicated no statistical significant mean differences between the beginning and the end of the backward skating for the maximum and minimum trunk segmental, hip, knee and ankle joint angles. However, the minimum hip joint angle was 91.5 ± 11.2° in the beginning of backward skating and 104.5 ± 15.2° ($p = 0.051$) at the end of backward skating, which approached significance. CONCLUSION: These preliminary findings suggest that physiological fatigue may change lower limb kinematics in backward ice hockey skating, and particular emphasis could potentially be placed on the hip flexion motion when prescribing a strength and conditioning program. Future studies are warranted to verify the findings from this study with a greater sample size and also conduct a 3D backward skating analysis that will enable understanding of hip abduction-adduction motion that 2D side view analysis could not detect.

P2-B-10 The Effects of Load Mass Variations on Front and Back Squat Movement Coordination Pattern

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BACKGROUND AND AIM: One of the most popular and important weight lifting core exercises is squat. Coaches, personal trainers, physical therapists, and sports physicians prescribe various types of squat exercise to athletes for injury prevention and sports performance improvement. However, without proper body joint coordination, an injury may occur easily when performing squatting exercise. Vakos, Nitz, Threlkeld, Shapiro and Horn (1994) have reported various serious injuries from squatting exercise that includes muscle and ligamentous sprains, ruptured intervertebral discs, spondylolysis, and spondylolisthesis. Previous studies defined coordination as a proper sequence of force production to produce an optimal outcome to achieve a task goal, and the examination of timing and sequencing of the movement using a shared positive contribution technique can provide a fundamental understanding in coordination (Northrip, Logan, & McKinney, 1983; Wu, Gervais, Baudin, & Bouffard, 2012). Therefore, the purpose of this study was to examine the effects of different load masses on both front and back squat movement coordination patterns. METHODS: After University-approved inform consents were obtained, male college football players who were experienced in front and back squat exercises participated in the study. Joint reflective markers were placed on the right side of their body at shoulder, hip, knee, ankle and toe. Each subject performed both squat exercises five repetition at 65%, 75% and 85% of one repetition maximum. A JVC camera was used to capture sagittal view of squat motion at 60 Hz. A standard 2D lower body kinematic analysis was conducted with Ariel Performance Analysis System software. RESULTS: A two-way repeated measured ANOVA was conducted at $\alpha = 0.05$ and followed by a t-test with Bonferroni adjustment when a significant difference was found. The results of this study showed no significant difference between two different squat exercises, and also no significant differences were found among all three mass loads. Both pairs of hip and knee and knee and ankle joints showed a strong simultaneous type of movement ranging between approximately 82 ± 11% to 123 ± 30% for the back squat and 87 ± 29% to 117 ± 27% for the front squat. Additionally, all athletes showed predominantly a proximal to distal type of joint coordination pattern. CONCLUSION: This study concludes that experienced athletes demonstrated a simultaneous type of movement in the lower body joints in both squat exercises. Even with increased load mass up to 85% of one repetition maximum, athletes were able to maintain a proximal to distal type of joint coordination pattern. Coaches and therapists may utilize these findings to ensure their athletes and patients have a proper squat joint coordination. Future research is warranted to examine EMG activity under various load masses on front and back squats.

P2-B-11 Effect of whole-body vibration on isokinetic performance and muscle activation in individuals submitted to Anterior Cruciate Ligament reconstruction

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Background and aim: The vibrating platform produces oscillations capable of causing mechanical stimuli and, according to the creators of the method, improve neuromuscular performance, balance and bone density. It is believed that the primary endings of muscle spindle are activated by vibration reaching the muscle belly, and therefore facilitate the activation of the alpha motor neurons, resulting in reflex muscle contraction. This study analyzed the immediate effects of whole-body vibration (WBV) on neuromuscular performance of the quadriceps femoris of subjects submitted to Anterior Cruciate Ligament (ACL) reconstruction. Methods: 44 male participants, between 14 and 18 weeks after ACL reconstruction, were submitted to an evaluation of isokinetic performance and surface electromyography of knee extensor muscles of the affected limb. The variables analyzed

were total work and the root mean square (RMS) of vastus lateralis muscle. Immediately after the evaluation, intervention protocols were carried out. Subjects were randomly allocated to one of the following groups: WBV group - performed an exercise protocol which consisted of staying barefoot in unipodal support on the non-dominant limb in the center of the vibrating platform, with 40o of knee flexion, while the upper limbs were extended at shoulder level and the trunk was kept in the upright position. The participants performed a total of 10 sets of 30 seconds, with rest intervals of 30 seconds between sets. The angle of the knee was monitored throughout the protocol with a universal goniometer to ensure that there were no changes in the amplitude. The vibrating platform was configured at a vibration frequency of 50 Hz and a vertical displacement amplitude of 4 mm; control group - performed the exercise protocol with the platform off. All participants were reassessed following the same procedure as the initial evaluation. The software SPSS (20.0) for windows was used for statistical analysis. A one-way ANOVA test was used to investigate baseline differences between groups. A two-way ANOVA for repeated measures was calculated to identify differences within and between pre- and post-tests. In the case of significance, post hoc comparisons (Bonferroni) were calculated additionally. A significance level of 5% was chosen. Results: No significant differences in anthropometric measures or variables analysed were observed in the baseline between the groups. There were no significant differences in total work nor in the value of the RMS in any of the groups. Conclusion: The results of this study suggest that the exercise protocol associated with WBV is not able to significantly improve the neuromuscular performance of the quadriceps femoris of subjects submitted to anterior cruciate ligament reconstruction.

P2-B-12 Effects of low level laser therapy on electromyographic activity after muscular fatigue: randomized, controlled, and blinded trial

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Background and aims: The muscle fatigue reduces athletic and funcional performance. The Low Level Laser Therapy (LLLT) acts in cells by promoting structural changes in organelles forming "giant" mitochondrias from the fusion of the neighboring mitochondria membranes, providing high levels of energy in celular respiration. This study aimed to investigate the immediate effects of Low Level Laser Therapy (LLLT) on neuromuscular activity after induced muscle fatigue. Methods: The study included 80 healthy subjects considered active or very active according to the IPAQ - Short questionnaire, aged between 18-28 years, without pain or injury in the dominant upper limb (UL). To record the electromyographic activity, electrodes were placed according to the recommendations of the SENIAM for the muscle

biceps brachial. Volunteers were positioned seated in the isokinetic dynamometer and submitted to 5 maximal concentric contractions of the elbow flexors. The analyzed variable were the root mean square (RMS) and median frequency of brachial biceps muscle. Immediately after the evaluation, participants underwent the intervention protocol. For the application of LLLT, a single-diode laser device, model Photon Laser III, was used with the following parameters: wavelength of 808 nm, power of 100 mw, total energy of 20 J distributed in 4 points (5 J per point) and application time of 49 sec per point. The volunteers were divided into 4 groups (n=20 each group). The fatigue protocol was standardized for all groups and consisted of 30 concentric contractions for the elbow flexor group, with an angular velocity of 120°/s on the isokinetic dynamometer. The placebo group received a simulation of laser application after initial evaluation; the pre-fatigue group received a laser application before the fatigue protocol; the post-fatigue laser volunteers were underwent laser application after induction of fatigue; and the control group remained at rest for 4 minutes before and after the fatigue protocol. The two-way ANOVA and Turkey post-hoc tests were applied and a significance level of 5 % was considered. Results: There was no difference between groups for the variables Root Mean Square (RMS) and median frequency (Fmed) after the interventions (p>0,05), demonstrating that the application of laser therapy did not significantly interfere in the electromyographic activity of brachial biceps muscle. Conclusion : The use of low level laser therapy did not cause significant effects on electromyographic activity after induced muscle fatigue in the biceps muscle of healthy subjects.

P2-B-13 Relationship between the transverse palmar arch in the hand and the intrinsic hand muscles during reach-to-grasp motion for an object of different size

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BACKGROUND AND AIM: A disorder of the intrinsic hand muscles such as ulnar nerve palsy decreases the distal transverse palmar arch in the hand and may result in hand flattening. Thus, the intrinsic hand muscles have an important role in a formation of the distal transverse palmar arch. The previous study indicated that different shape of an object alters the formation of the distal transverse palmar arch. However, it remains unclear whether the hand intrinsic muscle activities correlate with the formation of the distal transverse palmar arch, and the relationship between the distal transverse palmar arch and the hand intrinsic muscles changes in different object size. The purpose of this study was to examine the distal transverse palmar arch relates to the intrinsic hand muscles, and the alteration in object sizes affect the link between the distal transverse palmar arch and the intrinsic hand muscles during reach-to-grasp motion. METHODS: Ten healthy volunteers without any upper extremity dysfunctions participated in this study and performed a reach-to-grasp motion

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task. We used two different size spheres of small and large: a diameter of 100mm and 150mm. Nine retroreflective cameras motion analysis system (VENUS 3D) was used for recording the transverse palmar arch formation and simultaneously recording the muscle activities of thenar and hypothenar muscle during the task. Two arch angles of thumb and little and wrist extension angle were calculated using the motion analysis data. Root mean square (RMS) of thenar and hypothenar muscle activities were calculated using muscle activities data to evaluate the cross-correlation between the muscle activities and each angle. The angles and RMS were examined during one phase of motion: preshaping. We assessed the pattern similarity between each arch angle and intrinsic hand muscle activities using the cross-correlation coefficient. Further, we compared the average of each angle and the cross-correlation coefficient between two different object sizes while preshaping phase. RESULTS: The cross-correlation coefficient between the thumb arch angle and the thenar muscle activities in small and large sphere were 0.583 and 0.647, respectively. The cross-correlation coefficient between the little arch angle and the hypothenar muscle activities in small and large sphere were 0.671 and 0.656, respectively. There was a significant difference in the wrist extension angle between two object sizes; however, as for the both arch angles of thumb and little, there were no significant differences. The cross-correlation coefficient between thenar and hypothenar muscle activities was significantly higher in large sphere than in small one. CONCLUSIONS: These findings might show even if the object size changes, the relationship between the distal transverse palmar arch and intrinsic hand muscles has maintained; the coordination between intrinsic hand muscles changes in response to wrist extension angle.

P2-B-14 Supersonic Shear Imaging is a non-invasive method to early detect muscle damage

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Eccentric contractions are well-known as a damaging form of muscular exercise. To date, there is no non-invasive marker for early detection of muscle damage. The present study aimed to characterize the relationship between immediate changes in shear modulus (i.e., muscle stiffness) and force decrease 48 hours after eccentric exercise. Delayed onset muscular soreness, maximal strength, shear elastic modulus were quantified in 4 groups: elbow flexors (EF) "control" (i.e. concentric contractions; n=8), EF "mild" (n=12), knee extensors (KE) "mild" (n=12) and KE "severe" (n=10), before, 1 hour, and 48 hours after an eccentric exercise. No significant effect of time was found for "control" group. A significant immediate increase in shear modulus was found for EF (%2B 65.5%) and KE (%2B24.7% and

47.3% for "mild" and "severe", respectively) associated to a decrease of maximal muscle strength 48 hours after exercise (-24%). Significant correlations were found for EF "mild", and KE group ("mild" and "severe" pooled) between the immediate (1 hour) changes in shear modulus and MVC decreases 48 hours after exercise (r = 0.81 and r = -0.81 for EF "mild" and KE, respectively). This result is of great interest for the early detect of muscle damage after an eccentric exercise and, in turn, adjust the intensity of training or rehabilitation program in the next days.

P2-B-15 Effect of unilateral fatigue in the knee extensors on crank power during sprint cycling

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BACKGROUND AND AIM: Power production during sprint cycling is influenced by the force-generating capacity and activation level of lower limb muscles [1]. Because fatiguing unilateral knee extension exercises can reduce the force-generating capacity of the homologous contralateral muscles [2], such exercises could reduce ipsilateral and contralateral production of crank power during sprint cycling. We investigated the effect of unilateral isometric contractions on the force-generating capacities of the knee extensors and the transmission of power to both cranks during sprint cycling. METHODS: 12 adults performed a 4-s cycling sprint before and after a series of 30-s submaximal isometric voluntary contractions of the left knee extensors until isometric maximal voluntary force (IMVF) was decreased by 50%. IMVF of right and left knee extensors, as well as maximal voluntary activation (VA), maximal M-wave (Mmax) and resting twitch force (Qtw) of the left knee extensors were measured prior to and after the series of unilateral knee extensions. Average power transmitted to left and right cranks were calculated over the downstroke and upstroke phases of the cycles, while EMG of vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF) and semitendinosus (HAM) were measured on both legs. RESULTS: Left knee extensors' IMVF (618±149Nm to 292±85Nm), EMG/Mmax (VL: -35.8±17.3%; VM: -24.5±18.6%), VA (92±4% vs. 69±12%) and Qtw (-22±13%) were reduced after the unilateral contractions (all $P<0.05$). Left crank power decreased for downstroke (451±106W to 391±121W) and upstroke (67±32W to 55±29W). EMG of left VL, VM and HAM were reduced ($P<0.05$) but no changes were seen for RF during the sprint performed after the unilateral contractions. No changes in right knee extensors' IMVF and EMG were seen after the unilateral contractions ($P>0.05$), while right crank power was reduced ($P<0.05$) for downstroke (437±89W to 411±94W) and upstroke (72±28W to 64±26W). CONCLUSIONS: Unilateral knee extension exercise caused substantial levels of peripheral and central fatigue that led to large reductions (-52±11%) in the force-generating capacity of the ipsilateral knee

extensors and relatively small decreases of crank power produced by the ipsilateral limb during downstroke (-14±9%) and upstroke (-21±17%). Despite a lack of reduction in the force-generating capacity and EMG of the contralateral muscles, crank power produced by the contralateral limb was also diminished over downstroke and upstroke during sprint cycling. 1. Zajac, F.E., R.R. Neptune, and S.A. Kautz, Biomechanics and muscle coordination of human walking. Part I: introduction to concepts, power transfer, dynamics and simulations. Gait Posture, 2002. 16(3): p. 215-32. 2. Halperin, I., D. Copithorne, and D.G. Behm, Unilateral isometric muscle fatigue decreases force production and activation of contralateral knee extensors but not elbow flexors. Appl Physiol Nutr Metab, 2014. 39(12): p. 1338-44.

P2-B-16 The effect of external support on force and COP performance after ankle plantarflexors fatigue in athletes with ankle instability during lateral drop landing

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BACKGROUND AND AIM: Ankle sprain commonly occurs in the later period during matches or in prolong training because a constant muscle contraction leads to muscle fatigue. It is common for athletes using external ankle support but the effect under fatigued condition is still unknown. This study was to investigate the immediate changes of kinetics after ankle plantar flexors fatigue with or without external support. METHODS: Thirty-three athletes who had CAIT score less than 24 were identified with functional ankle instability (FAI) and were allocated to the control group (8M3F, age: 22.0±2.8 yr), the ankle brace group (8M3F, age: 22.5±1.9 yr), and the kinesio tape group (n=9M2F, age: 21.6±3.0 yr). All the participants performed single-legged lateral drop landing before and after plantar flexors fatigue protocol. The kinesio tape group applied kinesio tape on tibialis anterior, peroneus longus, and gastrocnemius; and the ankle brace group applied lace-up ankle brace during fatigue protocol and post-fatigue condition. The outcome measures were the difference of vertical ground reaction force (vGRF), the loading time, loading rate, and the range and velocity of center of pressure (COP) between pre-fatigue and post-fatigue measurement. The Kruskal-Wallis Test was performed to test the significance of median values of all dependent variables among the three groups; the post hoc test was then conducted for any group difference. RESULTS: In fatigue condition, the athletes without external support had a decreased peak vertical group reaction force and an increased COP range with faster COP velocity. However, the athletes with ankle brace had an increased peak vertical ground reaction force. For athletes with kinesio tape, they had a decreased postural sway and a decreased peak vertical ground reaction force in fatigued condition. CONCLUSIONS: Fatigue impaired dynamic postural control and the application of lace-up ankle brace provided ankle

joint stability and decreased postural sway. However, the passive constraint put ankle joint to sustain excessive force after landing. The use of kinesio tape provided ankle joint a better postural control and dissipated force during landing.

P2-B-17 The influence of kinesio tape and ankle brace on the lower extremity joint motion in fatigued unstable ankles during lateral drop landing

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BACKGROUND AND AIM: Ankle sprain often occurs after prolong training because of muscle fatigue. It is common for athletes to use external ankle support during training or matches; however, the effect under fatigued condition is still unknown. This study was to investigate the immediate changes of joint motion on lower extremity after ankle plantar flexors fatigue in the conditions with or without external support. METHODS: Thirty-three athletes who had CAIT score less than 24 were identified with functional ankle instability (FAI) and were allocated to the control group (8M3F, age: 22.0±2.8 yr), the ankle brace group (8M3F, age: 22.5±1.9 yr), and the kinesio tape (KT) group (n=9M2F, age: 21.6±3.0 yr). All the participants performed lateral drop landing before and after plantar flexors fatigue protocol. The kinesio tape group applied kinesio tape on tibialis anterior, peroneus longus, and gastrocnemius; and the ankle brace group applied lace-up ankle brace during fatigue protocol and post-fatigue condition. The outcome measures were the difference of maximal joint angle and the difference of range on hip, knee, and ankle joint angles between pre-fatigue and post-fatigue measurement. RESULTS: In fatigue condition, the athletes without external support performed lateral drop landing had greater joint motion. There was a significant group difference among three groups. Smaller difference of maximal hip abduction angle was found in the ankle brace group than that of the control group ($p=.011$); the KT group had a smaller difference of maximal ankle dorsiflexion than that of the control group ($p= .009$). In the difference of range of joint angle, there was group difference found in the hip and knee motion. The ankle brace group landed with a smaller difference of hip flexion than that of the KT group ($p=.008$). The difference of hip abduction in the control group was smaller than the ankle brace group ($p=.006$) and the KT group ($p=.045$); the difference of knee flexion was smaller in the ankle brace group than the control group ($p=.003$) and KT group ($p=.014$). CONCLUSIONS: Athletes without external support would adapt a flexion landing strategy after fatigue. The use of kinesio tape provided ankle joint a better landing position. With ankle brace, constraint on the distal joint motion could affect the range of motion in the proximal joints and resulted in a more extended landing posture. The changed landing strategy may contribute to the injury.

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P2-B-18 Development of a Diagnostic System for Shoulder Disorder Using Musculoskeletal Simulation

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BACKGROUND: The shoulder joint is quite important for human body, for its usage in wearing clothes, holding stuff or performing multiple daily activities. Shoulder discomfort is a common complaint in orthopedics clinic, and the etiology to younger age is trauma and sports-related injuries. For the old ones, the shoulder problems may relate to degenerative changes in the muscles, tendons, ligaments or cartilage wearing. Common diagnostic tools include history taking, physical examination, ultrasonography, arthrogram or magnetic resonance imaging (MRI). The physical examinations have no consistent results due to its relatively low sensitivity and specificity. Ultrasonography is a non-invasive and easily available tool for diagnosis and treatment, but has its limitations in clarifying complicated motions. Arthrogram is an invasive procedure, which the contrast medium will be injected into the joint for the subsequent X-ray series. MRI could obtain the detailed structure of the studies joint but the medial costs have restricted its utility. Musculoskeletal simulation technology is a convinced method to be applied in many fields, but few studies were focus on shoulder disorder. From the above, now lack of diagnosis method which is accurate can be used in clinic without motion limitation and it will be helpful for the patients who does not need to be arranged MRI. AIM: The purpose of this study is to employ musculoskeletal simulation technology (OpenSIM) to develop a diagnostic system. It is for the patients whose shoulder disorders is not serious, but still causing distress. METHODS: In this study, we used optical motion capture system with cameras to capture motion data. The patients with shoulder disorder are asked to capture their functional motions by these devices. The motion data were used for the musculoskeletal simulation in order to identify possible injured muscle groups. In the simulation, fiber length, tendon-force, moment-arm, etc. can be analyzed. These simulation data were provided to orthopedic doctor who would make diagnose. Finally, we confirm the diagnose with medical images. RESULTS: We captured different motions from subjects. These motion include rotation, flexion, extension, and some provocative tests movements. We find the main muscle in different motion by analyzing muscles length with OpenSIM software. In our study, we used fiber length variance of muscle to assume the degree of muscle injury so that we can give patients the diagnosis. CONCLUSIONS: Based on our result, shoulder disorder can be diagnosed with simulation. We suggested that diagnose shoulder disorder with simulation data is more convenient than traditional methods because our system can provide the accuracy and application in the clinic without motion limitation.

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P2-B-19 Reliability of the CANTAB cognitive assessment battery over short duration repeated measurements

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BACKGROUND AND AIM: Over the last thirty years, automated testing batteries, designed to assess various aspects of cognitive functioning, have become progressively common. One of these neuropsychological assessment batteries is CANTAB (Cambridge Neuropsychological Test Automated Battery). Research regarding the test-retest reliability of the CANTAB has been limited with only one known publication. METHODS: Twenty-three participants were randomly assigned into two groups, control (12 participants) and exercise (11 participants) and attended two sessions at least 5 days apart. An exercise group was included due to previous research in our lab examining the effects of heat stress on cognitive function during treadmill exercise. Five tests were utilized from the CANTAB battery: 1) spatial working memory (SWM), 2) reaction time (RTI), 3) rapid visual information processing (RVP), 4) spatial span (SSP), and 5) paired associates learning (PAL). Following baseline (Cog 1) testing (SWM, RTI, RVP), participants completed SSP and PAL while walking on the treadmill (4.5 km.h-1, 0% grade) and continued to walk for an additional 10 mins and then performed SSP and PAL (Cog 2). Upon completion, participants rested for 5 mins and then remounted the treadmill and walked for an additional 10 mins followed by administration of SSP and PAL (Cog 3). This work to rest ratio continued until participants completed Cog 5, at which time they were seated and completed SWM, RTI, and RVP. Intraclass correlations (ICC) and two-way ANOVA were conducted on all dependent measures. Statistical significance was set at ¦Á ¡Ü 0.01. RESULTS: Of the 28 ICCs determined, 17 revealed values greater than .60. For the two-way ANOVA analyses, only SWM total errors (28.5 ¡À 8.9 and 26.5 ¡À 12.9; 27.6 ¡À 17.5 and 18.2 ¡À 16.9) and RVP total correct rejections (251.9 ¡À 13.2 and 259.0 ¡À 8.3; 256.6 ¡À 11.6 and 260.7 ¡À 9.6) revealed a main effect of trial in the control group while SWM search time (910.4 ¡À 356.3 and 771.8 ¡À 238.5; 736.3 ¡À 198.7 and 658.6 ¡À 124.3 s) revealed a main effect of trial in the exercise group for test 1 and 2 in both sessions, respectively (p ¡Ü 0.01). CONCLUSIONS: Based on the ICC reliability values, the PAL test should be familiarized with up to 5 tests prior to data collection. In addition, SRT and CRT have relatively high reliability that indicate these measures can be used in test re-test comparisons of clinical and research designs. The SSP test provided an overall good reliability while the SWM test should provide enough baseline trials until participants determine an optimal strategy to minimize practice effects before test to test comparisons are made. Overall, to reduce practice effects a double baseline protocol should be implemented when changes in cognitive function over time are being examined. Furthermore, the addition of a non-experimental group will allow to distinguish between observed practice effects and changes due to the specific intervention imposed.

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P2-C-20 The skinny on vibration detection; how to generate skin feedback from the soles of the feet

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Background: The glabrous skin on the soles of the feet contain four distinct classes of cutaneous mechanoreceptors: fast adapting types I and II (FAI & FAII), and slowly adapting types I and II (SAI & SAII) [1]. Each class is sensitive to unique features of tactile stimuli, and may provide different functional cues to aid in the control of posture and gait. There is a growing research and clinical interest in enhancing cutaneous feedback through foot sole vibration [2, 3]. Previous work, which examined cutaneous receptors in the hand found frequency specific ranges of optimum afferent response for each class [4]. We do not currently know the vibration response characteristics of cutaneous classes in the foot sole. Aim: To investigate the vibration sensitivity and firing characteristics of low threshold cutaneous afferents across the human foot sole. Methods: Fifty-nine microneurography sessions in the tibial nerve were performed on 21 healthy subjects to obtain single unit cutaneous afferent recordings. Afferents were classified, and receptive fields mapped (Figure 1) based on previously described criteria [1]. Once identified, two-second vibrations at different frequencies (3-250Hz) and amplitudes (0.001-2mm) were delivered over each receptive field (6mm probe) driven by a vibration exciter (Mini-shaker 4810, Bruel & Kjaer, Denmark). Afferent firing characteristics were calculated from a representative one-second window of each vibratory burst. Impulses-per-cycle (imp/cycle), or entrainment response, was measured to establish the ability of afferent classes to entrain to each vibratory stimulus (fire 1:1). Results: Vibration responses were successfully collected from fifty-five cutaneous afferent recordings; 20 FAI, 10 FAII, 14 SAI and 11 SAII afferents (Figure 1). Each afferent class exhibited a unique capacity to respond at different frequency-amplitude combinations, however a broad overlap in responses was observed and an ability to preferentially isolate firing in each class was not apparent. All afferents were able to entrain at low frequencies (3-10Hz), while both SAs were unable to fire 1:1 above 30HZ. FA afferents had the greatest sensitivity (largest firing rate at low amplitudes) across all frequencies compared to SA afferents (even lower frequencies). Conclusions: Vibration was shown to evoke unique responses (imp/cycle) across the four foot sole cutaneous afferent classes. The ability to selectively activate a particular class in isolation was limited; however the overlapping thresholds and unique response intensities (imp/cycle) observed across classes may prove to have functional implications under loaded conditions. Understanding the interplay of afferent activation in isolation and as a population could lead to more targeted intervention strategies. References: [1] Kennedy, Inglis.(2002) JPhysiol. [2] Kavounoudias et al. (1998) Neuroreport. [3] Hijmans et al. (2007)Int J Rehabil Res [4] Johansson et al. (1982) Brain Res

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P2-C-21 The effects of an 8-week stabilization exercise program on trunk muscle thickness and activation as measured with ultrasound imaging in patients with chronic low back pain

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BACKGROUND AND AIM: Lumbar statilization exercise programs (LSEP) are popular but the underlying mechanisms are not well undestood. The aims were to determine if: (1) an 8-week LSEP in patients with chronic low back pain (CLBP) changed trunk muscle thickness and activation quantified by rehabilitative ultrasound imaging (RUSI); (2) RUSI measures were correlated with a change in clinical outcomes following the LSEP. METHODS: RUSI measures for the abdominal wall muscles [transversus abdominis (TrA), internal (IO) and external obliques (EO)] were taken in supine, at rest and during a contralateral active straight leg raise. Measures for lumbar multifidus were taken in prone, at 3 levels (L5S1, L4L5, L3L4), at rest and during contralateral shoulder flexion holding a small hand-held dumbbell. The RUSI variables were the resting muscle thickness (e.g., RIO or RL5S1) and percent thickness change due to contraction (e.g., %CIO or %CL5S1). RUSI measures were taken for the CLBP group (n = 34) before (T0) and after (T8) the 8-week LSEP (3 days/week %2B home exercises), along with Oswestry Disability Index (ODI) and Numeric Pain Rating Scale (NPRS) scores. RUSI measures were also taken for control subjects (n=30), at the same interval, but without treatment. Two-way ANOVAs (GROUP × TIME) were conducted to test for differences between patients and controls, and between measures collected at T0 and T8. Pearson correlations were carried out between RUSI measures at baseline (T0) and the change (d = T8 - T0) in clinical outcome measures (dODI and dNPRS). Partial correlations were also performed between the change of RUSI measures (e.g., dRIO) and the change in clinical measures, controlling for baseline RUSI measures. RESULTS: Patients reported a significant reduction in pain (NPRS; Cohen's d: 1.53) and improvement in function (ODI; d: 1.36). The ANOVA, however, showed no statistically significant GROUP × TIME interactions for RUSI measures, and only %CL5S1 (bilaterally) showed GROUP main effects (patients < controls). Significant and consistent (bilaterally) correlational analyses were only for thickness measures at rest: dREO (bilaterally) and dRIO (bilaterally) were correlated with dNPRS (r from 0.36 to 0.45); RL5S1 (bilaterally) were correlated with dODI (r = 0.43 and 0.46). CONCLUSIONS: The LSEP did not produce systematic changes in RUSI measures in the patients, relative to controls. Findings from the correlational analyses, however, first suggest that low LM thickness at baseline (RL5S1) may be prognostic for a reduction in perceived disability (dODI). Also, considering the distribution around zero of dREO and dRIO, suggesting muscle hypertrophy in some patients and atrophy in other, their positive correlations with dNPRS suggest that atrophy is related to decreased pain while hypertrophy is related to a less

decreased pain. This may reflect how successful the patients were at specifically recruiting the TrA, relative to EO and IO, during LSEP.

P2-C-22 A joint coordinate system to describe relative 3D motion between the front and head body segments of rodents: application in the study of neurodegenerative diseases

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SIGNIFICANCE: Parkinson disease (PD) is a neurodegenerative disorder where only recently instrumented motion analysis has been used to track progression and the effects of surgical or pharmaceutical treatment paradigms. However, because most drug trials for PD and other neurodegenerative diseases involve pre-assessment in models of the disease, translatable and accurate motion capture methods need to be developed for mouse models.
To the best of our knowledge, our group was the first to report, firstly on the feasibility of using an optical motion capture system to study aging-related changes on a mouse while walking, and secondly on a three body-segment rodent model comprised of the head, the anterior and hind body segments with application to PD. This model provided the ability to quantify and study the distinct 3D motion of each body segment relative to laboratory coordinates, using an Eulerian approach. However, much like when human motion is considered, it may be of greater interest if the motion of the rodent's body-segments are described relative to each other. Consequently, the purpose of this study is to expand on our previous work and propose a model to describe the 3D motion of the head of the rodent relative to the anterior body-segment.
METHODS: The development of the model has been described previously. Briefly, for the purposes of this report, one GDNF+/- mouse and a wildtype littermate (WT) were anesthetized and 2mm diameter retro-reflective markers were fixed to their hair via hypoallergenic double-sided tape. The markers were placed on the greater tubercle bilaterally, the middle of the back at the level of L4 to define the anterior body-segments. A marker was placed at the top of the head and two other virtual markers were created to define the head segment. A non-orthogonal joint coordinate system was created from the orthogonal systems of each body segment.
A 6-camera VICON optical capture system recording at 240Hz captured the 3D position of each marker. Each marker trajectory was low-pass filtered with a zero lag 6th order butterworth. Rodents walked freely in a 4 feet constrained walkway. For the purpose of this report, the model ultimately determined the relative angles between the anterior body-segment and the head assessing flexion/extension, tilting and spin in the sagittal, transverse

and frontal planes, respectively. The overall velocity of forward progression was estimated from the marker at L4.
RESULTS: The normal aging rodent walked almost twice as fast as its parkinsonian type counterpart. The sagittal and transverse motion of the WT was greater than that of the GDNF+/-. These results correlate well with the current knowledge about the motor deficits of individuals with PD.
CONCLUSION: The model presented, to the best of our knowledge, is the first to describe the relative 3D motion between the head and upper body of the rodent. The coordinate systems "ride" with the rodent and the angular displacements are not sequence dependent. Finally, our results appear to be clinically valid.
ACKNOWLEDGEMENT: Supported by NIH grant AG023630 and partly by the South Carolina Spinal Cord Injury Research Fund.

P2-C-23 Does continuous visual feedback mediate motor learning and consolidation? Insights into landing strategies based on extrinsic and intrinsic information

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Background: Landings may induce high impacts at collision with the ground, and thus, without feedback and without experience a single landing could have potential harming results (e.g., in elderly people). Impact forces at landing could be reduced by anticipation and control of joint stiffness (i.e., modulation of spring-like muscle properties), whereas proprioceptive mechanisms are relevant. We focus on these mechanisms and enhanced their use by precluding visual input before, during or after a series of landing trials. Using a drop-landing paradigm, we attempted to test the hypotheses that learning without vision enhances the use of joint proprioceptive control and, in turn, it would result in a better immediate performance and better memory consolidation one day after training. We expected reduction of impacts (impulse at collision) to be accompanied by concomitant changes in joint kinematics and dynamics (changes in stiffness), with a particular focus on the knee joint. Methods and Experimental Design: Twenty healthy female volunteers (age=23.45±1.9ys, height=163±6cm, weight=54±0.75kg) performed 30cm drop landings on both feet. Participants were randomly assigned to either Vision (V) or No Vision (NV) learning groups (10 blocks x 6 landings; 30sec rest between blocks), followed by a 6-min mental rehearsal and re-test sessions immediately after and in the following morning. Peak-Forces (PF), Time-to-Peak-Force (TP), rate of change of Force, knee joint-stiffness (K) and angular knee joint-kinematics were calculated and compared at different timelines (baseline, post-intervention, follow-up) in both groups ($p \leq 0.05$). Results: Learning was observed regardless of visual condition (lower impacts post-training), but baseline and follow-up differences were

only significant for the NV group in all measures. These effects were accompanied by concomitant modifications in knee kinematics and dynamics, with NV subjects learning faster and reaching lower impact forces at collision, also during the consolidation phases. Conclusion: Practice with no visual feedback may induce positive changes in daily performances where landings are required (sports, rehabilitation, jogging), with a reduction of the risk of damage (impacts at touchdown may be lower and strategies of control may be retained better). Modulation of joint stiffness may have been the (alternative) underlying strategy used when vision was precluded.

P2-C-24 Unaware motor response induced during biological movement visual stimulus -Physiological effects of an augmented reality system for therapy in sensory-motor disorders-

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BACKGROUND: We have developed a novel therapeutic system that administers an augmented reality for the recovery of sensory-motor function among patients with neurological conditions. Exposure to visual stimuli in this system induces a vivid impression as though one?s own body is moving or the intention of voluntary movement without actual movement (kinesthetic illusion induced by visual stimulus: KiNVIS). We have previously reported on the cerebral network activity (Kaneko et al. 2015) and increased corticospinal tract excitability (Kaneko et al. 2007) during KiNVIS. To elucidate the physiological mechanisms underlying KiNVIS, the present study examined involuntary motor response following exposure to the augmented reality system. METHODS: Eighteen subjects participated in five sessions a day for 5 days. Each testing day included one control session for static hand observation and four training sessions with moving hand observations. While in a comfortable chair with a headrest and wearing a head-mounted display, participants watched a real time picture (static condition) or a recorded movie (moving condition) of their right hand. The movie consisted of consecutive flexion-extension movements of the hand. The subjects were instructed to keep their hand relaxed at a semi-pronated position on a hand rest and to continue watching the display. Each session lasted a total of 5 minutes. Before and after training, the participants answered a questionnaire on self-body ownership and KiNVIS. Participants indicated their agreement with a presented sentence on a seven-item visual-analog scale ranging from ?agree strongly? (%2B3) to ?disagree strongly? (-3). To detect the involuntary hand movement, EMG was recorded from the flexor carpi radialis (FCR) and extensor carpi radialis (ECR) during each session. Root mean square (RMS) value and synchronicity of EMG movement patterns were calculated to quantify muscle activity. RMS amplitude was the sum of average RMS in the two muscles. High synchronicity values indicated cyclically repeated muscle activity synchronized with movement in the movie. RESULTS: Ownership was induced in 56% subjects before training. KiNVIS significantly increased after the training within each day compared to it before. However, 56% of subjects reported KiNVIS during the moving condition after the last testing session. The synchronicity increased as trials proceeded within each testing day. The main effect of day was significant among RMS values; it became smaller depending on the days. All subjects, from whom EMG was appeared, were not aware of their own response during the moving condition. CONCLUSIONS: The augmented reality system we developed induces automatic muscle activity of which the participant is unaware. This motor response corresponded to the represented movement with neither intension nor muscle co-contraction.

P2-C-25 Low back skin sensitivity has minimal impact on active lumbar spine proprioception and stability in healthy adults

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BACKGROUND AND AIM: To complete motor tasks and ensure stability of the lumbar spine, sensitivity of the proprioceptive and kinesthetic systems is necessary. Sensory feedback is relayed to the central nervous system with details relevant to the motor task being completed. In pain states, such as chronic low back pain (CLBP), research suggests that there is a deficit in tactile acuity [1]. Furthermore, these tactile acuity deficits have been suggested to predispose to the guarded/encumbered motor strategies associated with CLBP [2]. With this evidence, newer research has begun to investigate the efficacy of tactile acuity re-training as a potential means to alleviate pain and mitigate the sensorimotor effects of CLBP [e.g. 3]. The question remains however; do these observed deficits in tactile sensory acuity with CLBP (and their associated link with spine motor control) manifest through primarily peripheral or cortical mechanisms? The purpose of this research study was to assess the effects of peripheral tactile insensitivity alone on the motor control of the lumbar spine. METHODS: To reduce peripheral tactile sensitivity a topical lidocaine-prilocaine based anesthetic (EMLA®) was used and compared with an inert topical cream (PLACEBO). 28 healthy participants were divided equally into matched EMLA and PLACEBO treatment groups. Each treatment was applied to the skin of the low-back region; representing the region reportedly affected in CLBP [4]. Individuals completed tactile minimum monofilament and two-point discrimination (TPD) threshold assessments, assessments of sagittal and axial active lumbar spine repositioning error, seated balance control and repeated lifting dynamic stability. These assessments were administered both before and after the application of the EMLA or PLACEBO treatment. RESULTS: Low-back minimum monofilament and TPD thresholds were significantly increased within the EMLA group, demonstrating that EMLA

effectively reduced sensory inputs originating from the skin. Skin sensitivity remained unchanged in the PLACEBO group. In the EMLA group, decreases in low-back tactile sensitivity did not result in any consistent decline in lumbar spine proprioception (active sagittal and axial repositioning error) or dynamic stability (seated balance and repeated lifting). CONCLUSIONS: Decreases in peripheral tactile sensitivity observed here are similar in magnitude to those reported in CLBP patients (~60 mm TPD threshold, [1]). Within this healthy population, decreased tactile sensitivity of the low-back had minimal influence on active lumbar spine motor control. These results suggest that peripheral tactile insensitivities alone do not manifest in the observed motor control changes associated with CLBP.
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P2-C-26 Split-Belt Treadmill Adaptation in Transtibial Amputees

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BACKGROUND AND AIM: Split-belt adaptation paradigms have successfully been used to investigate sensorimotor learning in healthy control participants as well as patient populations. These studies suggest that both adaptation and de-adaptation (or washout) are strongly affected in the case of altered sensorimotor information ? experimental or pathologic. The current pilot study investigated split-belt adaptation in a group of transtibial amputees donning an intrinsically controlled, powered ankle-foot prosthesis in comparison to a control population. METHODS: Three transtibial amputees (2 unilateral, 1 bilateral) and three control participants took part in the study. During the trial, all amputees wore the BiOM ankle-foot prosthesis. Participants walked on a dual-belt instrumented platform and performed two baseline recordings at speeds of 0.5m/s and 1.0m/s (2mins respectively). Subsequently they performed a 10minute adaptation trial with the two belts running at speeds of 0.5m/s and 1.0m/s respectively (higher speed on affected side). This was followed by a 5minute wash-out phase with both belts set to 0.5m/s. Movement kinematics, ground-reaction forces, and electromyographic data were recorded. RESULTS and CONCLUSIONS The results of this pilot study illustrate that all amputees were able to successfully adapt their gait to the split-belt treadmill. Their data are discussed with respect to a) the performance of the control group, b) the (altered) neural mechanisms involved in sensorimotor adaptation as well as c) the importance such motor learning paradigms for the evaluation of prosthesis performance and as a potential indicator of successful prosthesis embodiment.

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P2-C-27 No gender effect in pinch grip coordination after lateral transfer in brain among stroke survivors

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No gender effect in pinch grip coordination after lateral transfer in brain among stroke survivors Seyed Hadi Salehi, Na Jin Seo University of Wisconsin Milwaukee BACKGROUND AND AIM: Within the concept of interhemispheric connectivity, technical modulation of the excitability of motor areas in the contralesional and ipsilesional hemisphere has been applied in an attempt to enhance recovery of hand function following stroke. Previous studies demonstrated that post stroke loss and recovery of sensorimotor function is associated with acute deterioration and subsequent retrieval of interhemispheric functional connectivity within the sensorimotor system. METHODS: The objective of this study was to determine the effect of gender on lateral transfer from non paretic to paretic hand in pinch grip coordination among stroke survivors. A total of 26 persons with stroke, 13 women and 13 men, participated in this study (57.61 ±9.42). The change in the paretic grip coordination before vs. immediately after learning the coordination with the non-paretic hand will be measured and compared between men and women post-stroke. The grip coordination was quantified from (1) The standard deviation of force value during pinch grip (std force); (2) The standard deviation of angle value during pinch grip (std angle); (3) The average angle of the force computed from the magnitude of shear force to normal force (average angle); and(4) the Maximum of the angle (max angle).The grip force coordination variables were computed for the 2 sec window at which the mean total force was the highest for that period. RESULTS: ANOVA was performed for all the variables in two methods in order to determine if Gender (women vs. men) significantly affects the improvement of pinch grip coordination after using non paretic hand grip. Std force and std angle were significantly dependent upon the interaction between gender and lateral transfer (ANOVA, $p<.01$). Std force for males was 23% significantly greater compared to females in pre lateral transfer phase (Tukey post-hoc, $p<0.01$). Std force significantly decreased 26% after lateral transfer in males (Tukey post-hoc, $p<.01$), whereas females did not significantly differ post lateral transfer ($p>.05$). std angle for males was 12 % significantly greater compared to females in pre lateral transfer phase (Tukey post-hoc, $p<.01$). Std angle decreased 23 % after lateral transfer in males (Tukey post-hoc, $p<.05$), whereas females did not significantly improve post lateral transfer ($p>.05$). CONCLUSIONS: The Stability of the pinch grip force among male significantly improved after learning from the non paretic hand trial compare to female. However, due to the significant difference in pinch grip coordination before lateral transfer among two groups, we failed to demonstrate any significant difference in gender on improvement of pinch grip coordination after lateral transfer in brain.

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P2-C-28 People with chronic low back pain show reduced movement complexity during daily activities

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BACKGROUND AND AIM: The quality of movement changes in people with low back pain (LBP). Most studies, however, have been conducted in laboratory conditions thus information about the complexity and variability of spinal movement during daily activities is largely unknown. Non negative matrix factorization (NMF) is used in multivariate analysis to describe a family of algorithms that aims at reducing the dimensionality of an observed dataset, and enhance its sub-structures and hidden regularities and thus provides an indirect measure of the complexity of a set of variables. Here we characterize the movement habits and the differences in movement complexity during daily activity between asymptomatic individuals and people with chronic LBP continuously measured over a 24-hours interval. METHODS: Thirteen people with mild chronic non-specific LBP and eleven age and gender-matched healthy individuals participated in this study. Spinal motion was detected using Epionics SPINE (Epionics Medical GmbH, Potsdam, Germany), a device consisting of two flexible sensor strips which are fixed paravertebrally to the spine to provide a dynamic assessment of spinal motion in a rapid and subject-specific manner based on strain gauge technology and acceleration sensors. After recording a brief quiet standing trial for calibration, the system was set to record for 24 hours consecutively and the participants were encouraged to engage in their normal activities. The orientation of the accelerometers was used to detect when the subjects were lying down and those intervals of time were marked as "resting". Accelerometric data was also used to detect movements and to mark the periods of the day where physical activity was maximal. RESULTS: The total resting time, the amount of movement, the average movements per hour and the percentage of time spent in each resting position (prone, supine, on left or right side) were computed. In addition, the inherent complexity of angle data was investigated during the 60 minutes of highest activity through NMF. Patients and controls spent a comparable amount of time lying down over the 24h period (average resting time 457,73 ± 103,83 and 448,26± 113,43 minutes for controls and patients, respectively, P = 0,95). People with LBP tended to move, in total, less than controls while lying down (controls 517,55 ± 391,36, patients 327,46 ± 256,27 movements, respectively, P = 0,04). The movements per hour also differed between groups (P = 0,015). The NMF highlighted a significant difference in the dimensionality of control for asymptomatic and LBP individuals, the latter showing an inherently less complex angle signal (controls: dimensionality 13,0±2,8, patients dimensionality: 10,2±2,6 modules, P = 0,002). CONCLUSIONS: The complexity of movement, investigated by means of NMF revealed that patients tend to use more stereotypical movements with limited relative independence across spine segments.

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P2-C-29 The potential functional consequences of the distribution of fat infiltration in the neck muscles

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BACKGROUND AND AIM: The temporal increase in neck muscle fat infiltration (MFI) has been shown to be related to poor functional recovery following whiplash. However, the complexity and time constraints of a quantitative analysis of MRI images may hinder translation into radiology clinical practice. In this study we employed a qualitative metric for grading MFI in the cervical multifidus muscle to assess its ability to detect changes in MFI in Whiplash-Associated Disorders (WAD). The results are used in a computational model to understand biomechanical consequences of MFI in the neck. METHODS: 31 subjects (14 male, 17 female, age 41.5 +/ -10.6, range 22-61 years) and 31 age and sex matched healthy controls were recruited from an ongoing randomized controlled trial at baseline. The inclusion criteria included neck disability index (NDI) scores that indicate at least mild pain-related disability of > 20% between 3 months and 3 years after a motor vehicle collision (MVC). The participants with whiplash were divided in two groups: mild to moderate disability (NDI 20 - 40%), and severe disability (NDI > 40%). The local ethics committee approved the study, and written informed consent was obtained from all participants. Phase sensitive reconstruction of the data was performed and the multifidus was identified and segmented by a blinded operator in the fat/water images (C4-C7), using Analyze 11.0 (AnalyzeDirect, USA). For each cervical level the multifidus muscle was manually divided in eight equally sized regions in two rows, with regions 1 and 5 closest to spinous process, and row 1-4 closest to the vertebra (see attached figure). MFI was assessed on a visually based on the fat images, according to: 0 for no or marginal MFI, 1 for light MFI, and 2 for distinct MFI. The mean regional MFI was subsequently compared between the healthy controls and each of the WAD groups. Statistical analysis was performed in SPSS 19 (IBM, 2010). RESULTS: Twenty-one (68%) of the patients had mild to moderate disability and 10 (32%) of the patients had severe disability. Statistically significant differences in the overall frequency of a grade '2' were found between healthy controls and severe WAD (p=0.03) and between healthy controls and mild/moderate WAD (p=0.03). Additionally, statistically significant differences in MFI were detected between the severe WAD group and healthy controls at the C4 level, but not for the mild/moderate WAD group when compared to the control or severe WAD groups. CONCLUSIONS: This study provides further evidence of higher amounts of MFI in the deep extensor muscles of participants with severe WAD when compared to those with mild/moderate WAD and healthy controls. The spatial distribution of MFI agreed with previous quantitative work showing higher fat percentages along the medial and anterior regions of the multifidus muscle in all groups, with globally elevated MFI magnitudes in the severe WAD group. The overall frequency of '2' scores turned out to best predict group

membership. The biomechanical consequences of the specific distribution of lost contractile tissue is currently being explored by altering maximum force production of deep neck muscles in a computational model of the neck.

P2-C-30 Measures of local dynamic stability at the ankle joint before and after a fatiguing protocol reveal subsets of polarised behaviours in young healthy adults

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BACKGROUND AND AIM Movement variability is an important construct in the field of human movement that is not very well understood, particularly in relation to fatigue. This study sought to investigate the effect of a fatiguing treadmill running protocol on local dynamic stability at the ankle. METHODS Eight healthy males (age: 21.8yrs±3.53; height: 181.4±6.13cm; mass: 76.7±6.59kg) training at least three times per week participated in this study. Participants first performed 10 minutes of steady state running at 60% of maximum heart, then completed 8 x 1 minute intervals at 80% maximum heart rate with 30 seconds recovery, followed by another 10 minutes of steady state running at 60% maximum heart rate. Sagittal plane ankle angle data were recorded for 2 X 180 second periods (1-3 minutes and 5-8 minutes) during both 10 minute steady state runs. Fifty consecutive strides of data were selected from each trial to create a time series of ankle angle data. The Lyapunov Exponent (LyE), a measure of local dynamic stability, was computed. A paired t-test was used to investigate the stability of the two "baseline" (i.e. pre fatigue) recordings. A one-way repeated -measures ANOVA was carried out to examine the effect of fatigue and recovery at three different time points i.e. baseline, post fatigue 1 and post fatigue 2. RESULTS No differences were observed between baseline measures, indicating the LyE was a stable measure in this population. A one-way repeated-measures ANOVA resulted a non-significant effect of fatigue (p=0.9). On visual inspection it was noted that half of the group demonstrated a marked increase in variability due to fatigue, while the other half demonstrated a marked decrease, resulting in a mean cancellation effect across the group. Further analysis was performed on the sub-groups, finding that the increased variability group yielded a significant difference (p=0.014) between baseline and post fatigue 1 (p=0.043) and post fatigue 1 and post fatigue 2 (p=0.022). A significant difference (p=0.024) was also shown in the decreased variability group between baseline and post fatigue 1 (p=0.039). CONCLUSIONS Fatigue is an organismic constraint that results in diverse adaptations within a group of healthy athletes. It is not possible to conclude what strategy is "better" in this instance: increasing or decreasing the LyE. The results of this study require us

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to acknowledge that group analyses of movement strategies adopted in the presence of fatigue may mask important information.

P2-E-31 Impact of amyotrophic lateral sclerosis in the system stomatognatic

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BACKGROUND AND AIM: Amyotrophic lateral sclerosis (ALS) is a neurodegenerative and progressive disease that affects the neuromotor system preventing the proper muscle function. This disease has in 10% of cases genetic characteristics, and the other 90% are sporadic. So that the human being has the quality of life it is necessary to a harmonious development of the skeletal muscular system and any changes in this complex system will cause imbalance in the stomatognathic system. This research evaluated the effects of ALS on EMG activity of masseter and temporalis muscles. METHODS: 30 individuals of both genders, with a mean age of 30.3 ± 5 years, matched individual to individual and distributed into two groups with 15 subjects each: GI with ALS and GII healthy control. This study was approved by the Ethics Committee of the Ribeirão Preto Dental School, University of São Paulo. The evaluation of EMG activity was carried out by EMG recordings of the right masseter (RM), left masseter (LT), right temporal (RT), left temporal (LT) during postural condition of rest (4s); dental clenching (4s); right laterality (10s,) left laterality and protrusion (10s). Surface EMG was performed using the Myosystem-Br1. Individuals with ALS were diagnosed by medical experts of the Department of Neuroscience and Behavioral Sciences at the Faculty of Medicine of Ribeirão Preto / USP. The mean values were normalized by the value of the EMG signal of dental clenching in maximal voluntary contraction (4s). The average EMG were tabulated and submitted to statistical analysis by the independent t-test (SPSS 21.0). RESULTS: The normalized EMG activity was significant ($P < 0.05$) for the rest: RM = [(I = 0.16 ± 0.06), (II=0.05 ± 0.01)] and LM= [(I = 0.18 ± 0.06), (II = 0.05 ± 0.01)]; protrusion: LM= [(I = 0.45 ± 0.07) (II = 0.12 ± 0.02)]; RT = [(I = 0.19 ±0.03), (II = 0, 09 ± 0.01)] and LT = [(I = 0.23 ± 0.06) (II =0.10 ± 0.02)]; left laterality: RM = [(I = 0.31 ± 0.06) (II = 0.09 ± 0.02)]; LM = [(I = 0.41 ± 0.08), (II = 0 09 ±0.02)] and LT = [(I = 0.32 ±0.07) (II = 0.17 ± 0.03)]. CONCLUSION: According to the results it can be concluded that there were significant changes in the activation pattern of the masticatory muscles in patients with ALS, as they possessed greater muscle activity when compared to healthy individuals. ACKNOWLEDGEMENT: FAPESP

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P2-E-32 Acupuncture applied to the branches of the facial nerve for the rehabilitation of bell's facial paralysis

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AIM: The peripheral facial paralysis is caused by a nervous influx interruption in any one of the segments of the facial nerve due to the invasion of exogenous pathogenic wind and cold, leading to an obstruction in the movement of energy and blood in the face. This condition results in malnutrition of the muscle tissues and consequently motor impairment. The objective of this study was to evaluate the effects of acupuncture on the branches of the facial nerve using electromyography and facial expressions. METHODS: A 45-year-old man diagnosed with Bell's facial palsy on the right side participated in this study. The patient was submitted to surface electromyography with the electrodes being positioned on the orbicularis oris and the orbicularis oculi muscles, and to facial expressions to obtain images prior to and after rehabilitation, which consisted of 10 sessions once a week of acupuncture along the facial nerve, using tsing needles. RESULTS: The comparative analyses of the electromyographic images showed an increase in the action potential of both oris and oculi orbicularis muscles on the affected side, following the acupuncture sessions. For the upper orbicularis oris (UOO) and the lower orbicularis oris (LOO) muscles, the results were obtained during clinical conditions of rest (UOM: pre=7.18; post=27.44), (LOO: pre=69.83; post=312.46), beak (UOO: pre=106.80; post=127.13), (LOO: pre=554.38; post=747.59) and lip pressure (UOO: pre=86.04; post=253.76); (LOO: pre=512.31; post=872.36). For the upper orbicularis oculi (UOO) and the lower orbicularis oculi (LOO) muscles, the results were obtained during the clinical conditions of rest (UOO: pre=18.38; post=31.09); (LOO: pre=3.23; post=4.59) and blinking (UOO: pre=15.55; post=31.99); (LOO: pre=2.65; post=37.16). In relation to the visual feedback provided by the obtained images, the facial symmetry was restored compared to the hemi-faces. CONCLUSION: The results showed that acupuncture applied to the branches of the facial nerve can provide greater muscle action potential and recruitment of the muscle fibers in the affected side by clearing the normal flow of energy, improving the function of the movements, and providing better symmetry and positive responses in the stomatognatic system.

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P2-E-33 Finger movement control and associated brain activity responses post-stroke

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BACKGROUND AND AIM: Impaired finger dexterity is common after stroke, often affecting activities of daily living. Knowledge of kinematic characteristics and of underlying neurological mechanisms of such impairments is important to understand functional recovery. This study aims to investigate finger movement control and related brain activity patterns post-stroke (PS). METHODS: Data from a subsample including 9 participants PS with residual hemiparesis affecting manual dexterity (M age- 66; 3 female) and 12 able-bodied control (C) participants (M age- 65; 3 female) were analyzed. Two series of self-paced cyclic finger extension-flexion movements in random order were performed for each hand (4 series with vision, V, and 4 without vision, NV). Optoelectronic cameras monitored the 3D movement of markers affixed to the fingertips. Motion data was used to calculate each finger's Individuation index (II), reflecting movement independence, each finger's Stationarity index (SI), reflecting the ability to keep the finger still while another moves [1] and Movement frequency (MF). Functional magnetic resonance imaging, with simultaneous movement recording, was used to investigate brain activity patterns in relation to the kinematic parameters. II, SI, MF and the effect of vision were analyzed for the 4th digit. RESULTS: A factorial ANOVA 2 [group] x 2 [condition] x 2 [side] x [index type] showed an effect for group ($p < .0001$; PS < C); condition ($p < .01$; NV < V); side ($p < .0001$; affected/non-preferred < non-affected/preferred); and index type ($p < .0001$; SI < II). An interaction between group and side ($p < .01$) showed that indices of the affected side were lower compared to the non-affected side within the PS group and compared to both sides in the C group. No significant effects were apparent for MF but significant correlations were found between the indices and MF that were restricted to the PS group alone (over all conditions- $r = -0.22$; $p < .01$; within the NV condition- $r = -0.19$; $p < .01$; within the affected side $r = -0.15$; $p < .05$; and within the SI categorization $r = -0.14$; $p < .05$). Furthermore, within NV for the non-affected hand on the SI alone ($r = -0.54$; $p < .05$). All indicate that slower movements had higher indices. DISCUSSION: The associations between slower MF and higher index values within the PS group were located to conditions with increased difficulty (NV, affected side, and SI). Thus, reducing speed may be a selected strategy to increase control of finger movements PS when the demand on motor control is high. Further, with the applied calculation of finger movement independence we were able detect group differences, side differences within the PS group, and a positive effect of vision of the hands during performance. This indicates that this calculation is a sensitive measure that could be used to study the effects of stroke and to monitor progression in motor recovery. [1] Häger-Ross & Schieber, 2000, J Neurosci 20:8542-50

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P2-E-34 Concentric and isometric torques are affected by diabetes but the eccentric remains unchanged due to diabetes or polyneuropathy

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Introduction: The properties of muscle contraction of diabetic patients is poorly described and understood. Different from the sensorial losses, muscle weakness is only observed in the most compromised patients, while the early alterations are not addressed at all. Many movements disorders are described in the literature and, nowadays, are a public health issue, such as foot ulcers, amputation, and falls, yet insufficient information are available that refers to muscle impairments and their relationship with those severe complications. Since preserved muscle function is vital to maintain balance and stability during daily living tasks, it is necessary to understand muscle behavior in different status of the disease. Aim: Investigate knee and ankle joint torques during concentric, eccentric and isometric contractions in diabetic and neuropathic patients comparing them to non-diabetic individuals. We hypothesized that torques will be diminished in diabetics and even worse in neuropathic patients; also the ankle losses would be greater than the knee, because the polyneuropathy is supposed to have a distal to proximal involvement. Methods: The peak torques of flexion and extension for both joints were acquired using an isokinetic dynamometer in sitting position. During concentric and eccentric contractions, the joint speed was set at 60°/s. Five maximal voluntary contractions were acquired for concentric and eccentric and 2 for isometric, with a rest interval of 1.5 minutes. The sequence of the tests was randomized and verbal and visual feedback were standardized and delivered to all subjects. Three groups of adult males were evaluated (1) Control group (healthy non-diabetic individuals, n=33), (2) Diabetic group (patients with diabetes mellitus, n=31), (3) Neuropathic group (patients with diabetic polyneuropathy, n=28). The Neuropathic group was defined according to a fuzzy model of signs and symptoms. Differences between groups were calculated with ANOVAs for parametric knee variables (α of 5%) and Mann Whitney and Willcoxon for non-parametric ankle variables (adjusted α of 1.6%). To describe effect sizes, Hedges' g coefficients were calculated. Results and Discussion: Irrespective of polyneuropathy, both diabetic groups presented lower knee and ankle flexion-extension torques, both for isometric and concentric contractions. Other factors beside the polyneuropathy and early diabetes onset may be influencing the muscle strength production. The eccentric contraction was not different between any group that may suggest that passive muscle structures, which act on strength production, may not be affected by neuropathy or by diabetes. Other surprising finding was that knee and ankle torques presented a similar decrease between them, with greater effect sizes for the knee flexion and extension. This result does not support the hypothesis of a distal to proximal impairment, which was already demonstrated for the sensorial component of polyneuropathy.

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P2-E-35 Effect of back pain on trunk strength capacity and muscle activity patterns during isokinetic and sudden trunk loading in adolescent athletes

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BACKGROUND AND AIM: Maximum strength, trunk muscle activity and compensation of sudden trunk loading are regarded important factors in achieving core stability, with respect to back pain prevention. The purpose of this study was to evaluate differences between adolescent athletes with (BP) and without back pain (NBP) in maximum trunk strength and muscle activity during isokinetic (ISO) and sudden trunk loading (STL) situations. METHODS: 9 adolescent athletes with load induced back pain (BP: m/f 2/7; 15.6±1.2 y; 177±9 cm; 67±13 kg; 22.5±9.8 h/week training in canoe, rowing or triathlon) and 9 matched athletes without back pain (m/f 2/7; 15.7±1.4 y; 177±12 cm; 65±9 kg; 16.5±8.0 h/week training) were included in the study. Maximum strength in right-sided trunk rotation (ROM: 31°) as well as flexion/extension (ROM: 55°) was assessed on an isokinetic dynamometer (isometric; concentric/eccentric 30°/s). Sudden trunk loading (STL) was measured during eccentric extension and rotation (30°/s) with an additional dynamometer induced novel perturbation (acceleration from 30°/s to 330°/s within 120ms for rotation and to 150°/s within 250ms for extension) as a marker of core stability. Trunk muscle activity was assessed using a 12 lead-EMG including 6 ventral (Mm rec. abd., obl. ext. abd., obl. int. abd, left and right side) and 6 dorsal (Mm erec. spinae thoracic and lumbar, latis. dorsi, left and right side) muscles. Peak torque [Nm] and MVC normalized EMG-amplitudes (RMS) were calculated for each test condition and all single muscles as main outcome measures. Additionally, the mean EMG-RMS for four areas of the trunk was calculated (right and left ventral area (Vr / Vl), right and left dorsal area (Dr / Dl)). Descriptive statistics (mean±SD) were followed by interferential statistics using t-test (á<0.05). RESULTS: BP showed reduced peak torque for ISO and STL in extension and flexion, but not for trunk rotation (e.g. STL for BP/NBP: extension: 251±57/336±73Nm p<0.05, rotation: 144±45/138±37Nm p>0.05). EMG amplitudes were increased for back muscles (Dr, Dl) during concentric, eccentric and STL trunk rotation as well as extension/flexion compared to NBP (STL for BP/NBP: extension (Dl): 72±13/97±31% p=0.065, extension (Dr): 66±15/87±21% p<0.05; rotation (Dr): 48±26/137±86% p<0.05, (Dl): 39±25/74±43% p<0.05). No differences between groups were present for the abdominal (Vr / Vl) muscles (p>0.05). CONCLUSIONS: Adolescent athletes with back pain present characteristic trunk reaction pattern with reduced extension/flexion strength and higher back muscle activity in all test conditions. Therefore, the evaluation of strength and muscle activity in sudden trunk loading is suitable to assess altered trunk function which might be discussed in the background of reduced core stability. Training interventions focusing not only on trunk strength capacity but also on improving neuromuscular function should be recommended for affected adolescent athletes.

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P2-E-36 Complex Shoulder Instability - Chicken or Egg?

BACKGROUND AND AIM: The pathophysiology of type II/III shoulder instability using the Stanmore Classification System is not fully understood. This is the first study to approach this group of patients with complex shoulder instability from a muscle activity analysis perspective. The aim of this study is to identify whether the dysfunctional muscle patterning caused (egg) the instability or was part of a compensatory strategy (chicken).

METHODS: A total of thirty two patients including sixteen patients with Polar type II/III shoulder instability and sixteen age-matched controls were recruited. Polar type II/III shoulder instability was confirmed jointly by a senior upper limb surgeon and specialist physiotherapist. Activation of several muscles around the shoulder girdle including anterior deltoid (AD); middle deltoid (MD), posterior deltoid (PD), upper trapezium (UT), serratus anterior (SA), biceps brachii (BB), teres major (TM), latissimus dorsi (LD), pectoralis major (PM), supraspinatus (SSP), infraspinatus (ISP) and subscapularis (SUB) was assessed by EMG during forward flexion and abduction in the standing position. Each movement was divided into Phase 1 (up-swing) and Phase 2 (downward stroke). Both the patients and the controls also completed a number of questionnaires including the Western Ontario Shoulder Instability Index (WOSI), Oxford Shoulder Instability Score (OSIS) and Beck?s Depression Inventory.

RESULTS: Forward Flexion - The level of activation (%EMGmax) for all muscles was significantly higher in the patient group as compared the control group. In the patient group, it ranged from 86-112% in phase 1 and 78-103% in phase 2, as compared to 38-73% in phase 1 and 8-71% in phase 2 for the control group. There was a profound difference in the activation patterns of muscles in the patient group, with much greater variation and increased activation.

Adduction - In phase 1, activation of AD, MD, UT, TM, LD, BB and ISP was delayed in the patient compared to the control group. Furthermore, the peak activation of PD, SA and PM in patients occurred earlier that in the control group. In phase 2, AD, MD, PD, UT, SA, LD, BB and ISP showed delayed activation in the patient group.

The WOSI and OSIS showed a dramatically different score in the patient group compared to the controls.

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CONCLUSIONS: It is important to remember that the shoulder structure is intact in this group of patients. This is different to other shoulder pathologies such as rotator cuff injuries, where the compensatory strategies arise from structural abnormalities. Widespread aberrant muscle activation was seen in the patient group. We propose the activation patterns seen in these patients simultaneously demonstrates dysfunction and the compensatory strategies they employed to achieve even simple shoulder movement ? both chicken and egg!

P2-E-37 Functional analysis of lower limbs in individuals infected with the human immunodeficiency virus

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AIM: Acquired Immunodeficiency Syndrome (AIDS) is a chronic, incurable, viral disease complex transmitted by the blood, semen, breast milk, and vaginal fluids of infected patients. We aimed to investigate the physical, biological, and psychosocial factors relevant to the development of musculoskeletal diseases in patients with the human immunodeficiency virus (HIV), and to analyze the relationship between these factors and the symptoms of AIDS. The objective is to understand how HIV type 1 affects the function of the lower limb muscles. METHODS: Sixty men and women aged 22 to 57 years (mean of 36.77± 9.33 years) were selected and divided into two groups: 30 individuals with HIV subtype 1 (experimental group), and 30 healthy individuals (control group). Muscle activity was evaluated using electromyography. In order to analyze daily habits, measurements were made while the subjects assumed the following positions: orthostatic, squat (normalization factor), chair lift, seated on a chair, climbing and descending steps bilaterally, and mono support bilaterally. The final data were statistically analyzed by t-test using the Statistical Package for the Social Science, Version 21.0. RESULTS: Normalized electromyographic data of static posture in relation to lower limb support revealed to HIVG, a predominance of muscle activation to the right semitendinosus and left gluteus medius with left and right unipodal support. For the CG, the prevalence of muscle activation was observed on the left and right rectus femoris. For electromyographic analysis of functional activities of lower limbs revealed a predominance of muscle activation to the left rectus femoris and left gluteus medius during left and right climb "step", left and right lower "step", and chair lift and sit. For the CG, predominance of muscle activation was observed in the tensor fasciae latae. CONCLUSION:

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Analysis of functional muscle activity of the lower limbs in AIDS patients revealed a predominance of muscle activation to the left rectus femoris and left gluteus medius. Thus, in this study it is possible to observe that individuals with HIV demonstrated changes in the functional activity of the lower limbs.

P2-E-38 A systematic review of torso motor control impairments in adolescents with idiopathic scoliosis (ais) with implications for the planning of conservative interventions

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Fiber type abnormalities affect AIS. However, because of the conflicting knowledge on muscles in the etiology and progression of AIS, a review is needed. Scoliosis exercise schools have not stated their rationale based on deficits of torso muscles. Such evidence could inform exercise prescription.To systematically review the literature on differences in EMG activity of the erector spinae (ES) and abdominal muscles in AIS compared to healthy controls.A search was done in EMBASE, MEDLINE, CINAHL, Pedro, and Web of Science. Free text and indexed terms on scoliosis or spinal deformity were combined using AND with: strength, endurance, fatigability, muscle fatigue, latency, co-activation, EMG activity or timing. The references of included articles were checked. Two reviewers screened abstracts, then full-text articles using the inclusion criteria: in English or French; AIS; on torso motor control. Exclusion criteria were: post-operative or post-exercise; or <10 subjects. The Newcastle/Ottawa (NO) scale and ISEK EMG criteria were used for quality appraisal. PRISMA guidelines were used.The search yielded 10887 hits (6534 unique). After screening abstracts, 98 full-texts were reviewed and 12 included. Agreement for abstracts screen was Kappa = 0.79. Only 1 study had high (>80%) quality on ISEK criteria. Studies often missed electrode size (68%), or type (59%). Only 3 studies had high (>80%) NO quality. Most samples were <25 (10 to 394). Comparing groups, limited evidence from 2 low quality studies shows longer latencies in ES for a drop step test and to neck extension in progressive curves. Limited evidence from 1 high quality study shows no difference in normalized ES activity during 2min of isometric extension using 3 intensities and 2 sitting positions. Limited evidence from 1 low quality isometric hyperextension study shows lower EMG on the concave side and no difference in fatigue index. For dynamic lateral bending and rotation voluntary tasks in sitting or standing, there is limited evidence from 2 low quality studies of higher activity in ES and from 1 study in obliques and rectus. Limited high quality evidence (2 studies) shows higher activity or hetero to homolateral ratios in ES and bicep femoris during forward and backward perturbations. During walking, there is limited evidence (1 high, 1 low quality) of prolonged duration of ES and quadratum activity with conflicting evidence about

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duration in gluteus maximus. From low quality isokinetic flex-ext. studies at 20-90o/s, there is limited evidence of decreased median frequency in ES on the right thoracic side, of more symmetrical activity for the Lumbar ES and of increase thoracic ES activity on the dominant side in large curves.Patients with AIS present latency, endurance, and EMG deficits possibly more important in patients with progressive curves. Future studies should determine if deficits predict progression and if modifying these deficits with exercises can prevent curve progression.

P2-E-39 Effects of low vision and blindness in complex postural

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BACKGROUND AND AIM: Posture is characterized as being a position maintained with automatic and spontaneous characteristics, requiring little muscular activity to keep it. The visual system is responsible for 80% of the information sent is essential to motor development. Low vision or its absence limits the life experience and influences the development. Electromyography (EMG) is a technique that allows the recording of electrical signals generated by muscle cells. This study evaluated the EMG activity of the masticatory muscles, cervical and shoulder girdle of individuals with low vision and blindness, compared to a healthy group. METHODS: 30 individuals analyzed between 18 to 40 years, divided into two groups: those with low vision and blindness (GI, n = 15) and healthy control (GII, n = 15). Exclusion criteria were: the presence of disorders of systemic or local origin, using medications or treatments that may interfere with the muscular activity, under the age of 18 years and people with cognitive problems. EMG examination were performed (Myosystem-Br1) for right masseter (RM), left masseter (LM), right temporal (RT), left temporal (LT), esternocleidomastoideo right (RECOM), left sternocleidomastoid (LECOM), top right trapezius (TRT), top left trapezius (TLT), right middle trapezius (RMT), left middle trapezius (LMT), along the right chest (ARC) and along the left chest (ALC), the following conditions for the masticatory muscles : dental clenching in maximum voluntary contraction (4s), dental clenching in maximum voluntary contraction with Parafilm M®; placed on both sides of the dental arch (4s), right laterally (10s), left laterally (10s), chewing of peanuts (10s) and chewing of raisins (10s). For the cervical muscles: cervical flexions (10s), shoulder flexion (10s), shoulder abduction (10s) and stem extension (10s). The EMG data were tabulated and submitted to statistical analysis (SPSS version 21.0). This study was approved by the Ethics of

the University of São Paulo / School of Dentistry of Ribeirão Preto. RESULTS: The EMG activity was significant (P<0.05) in the mandibular rest: LM= [(I = 5.47 ± 1.25), (II = 9.28 ± 1.01)], LT = [(I = 1.57 ± 0.16), (II = 5.41 ± 0.81)], right laterality: LT = [(I = 2.77 ± 0.16) (± 5.71 II = 0, 81)]; the shoulder flexion: TRT = [(I = 91.80 ± 13.58) (± 12.95 139.72 = II)], TLT = [(I = 162.01 ± 47.56), (II = 390.67 ± 63.04)]; the shoulder abduction: LMT = [(I = 11.14 ± 0.97) (± 18.33 II = 2.61)]; in the extension of the spine at rest: ALC = [(I = 7.78 ± 1.65), (II = 17.51 ± 3.94]. CONCLUSION: Based on the results, there was greater potential for action of muscles of the face, indicating change in biomechanics of the stomatognathic system, and a reduction of responses of automatic adjustment of the posture, referring to individuals to a compensatory attitude. ACKNOWLEDGEMENT: PIBIC / USP / CNPq.

P2-E-40 Superficial tissue compression effects in muscle tone of patients with encephalic vascular accident

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AIM: The spastic hypertonic is a common clinical manifestation in patients with cerebrovascular alterations, resulting in motor disability, during the daily life activities. The objective of the present study was to analyze the effects of a tissue compression device (TCD) in the muscle activity of upper hemiparetic limb in patients with stroke (ST). METHODS: This study was previously approved by the Ethics Committee in Research of the School of Physical Therapy of Bebedouro, UNIFAFIBE. Fourteen male individuals, aged 60 to 80 years (72,33± 2,36 years) and clinical diagnosis of ischemic stroke (STi), were selected and divided in two groups: ten individuals with right spastic hemiparesis and four individuals with left spastic hemiparesis (Ashworth 2 and 3). All subjects underwent muscle activity, through surface electromyography, pre and post immediate application of TCD. For the application of the device the individuals remained with a "float" that promotes a compression in the tissue surface of the member, in a period of 15 minutes, maintaining the orthostatic position and with upper limbs held in neutral position (according to the spastic pattern). A pressure control, kept in a nominal scale 1,0psi, controlled with a pressure gauge. Surface electromyography was performed using the EMG-Br1 Myosystem®, during the clinical condition of rest (10s). The values were normalized by the value of the electromyographic signal of isometric contraction of each muscle evaluated, harvested by ten seconds. The electrodes were placed on the following muscle: biceps brachii (BB), triceps brachii (TB) and brachioradialis (BR) of the affected side (hemiparetic). The electromyographic means were tabulated and subjected to statistical analysis using t test (SPSS version 21.0). RESULTS: After

applying the TCD based on a descriptive analysis, showed that all the muscles evaluated presented a lower muscle activity. However the results were not statistically significant, as regards the comparison of the two periods (t-test $p > 0.05$). CONCLUSION: The TCD was effective in reducing the spastic muscles activity, for the muscles BB, TB and BR, due the device cover the entire length of the upper limb, acting directly on muscle fiber and promoting direct stimulus to mechanoreceptors. It is believed that with the spastic reduction, the patients may acquire standard major functions in daily activities, thereby improving their quality of life and preventing possible complications such as bone and muscles deformities.

P2-E-41 Investigation of Oxygenation Difference during Sternocleidomastoid Isometric Contraction for Clients with Mechanical Neck Disorder

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BACKGROUND AND AIM: Previous study demonstrated that 66% of people have experienced neck pain during their lives. Mechanical neck disorder (MND) has become one of the most severe musculoskeletal symptoms. The clinical symptoms of MND include neck pain, muscle imbalances and restricted activity. Furthermore, patients with MND may easily experience the over-activation of EMG signal on the upper trapezius muscle and the sternocleidomastoid, which lead to fatigue of the superficial neck muscle groups. The oxygen in blood played an important role on ameliorating fatigue led by over-activation of muscle. However, it remained no data available for the condition of oxygen-hemoglobin in MND patients. In this study, we explore oxygen-hemoglobin concentration of sternocleidomastoid muscle during execution basic actions in MND patients. METHODS: The study was carried out by 27 adults, including healthy participants without neck-related symptoms ($n = 13$; 9 males and 5 females, 24.0 ± 5.1 yr) and MND clients with Neck Disability Index (NDI) more than mild disability ($n = 14$; NDI: 9.23 ± 4.00, 7 males and 6 females, 23.6 ± 4.2 yr). The participants were requested to remain supine position on the bed. The concentrations of oxygen-hemoglobin/total hemoglobin were measured triplicate on sternocleidomastoid muscle belly by near-infrared spectroscopy when performing 25%/50% maximum voluntary contraction of neck flexion (30 sec of each). Hyperbolic tangent method (tanh) was applied to analyzed the parameters of oxygenation kinetic. The differences of the tissue oxygen saturation (ÄStO2) were calculated from the baseline contraction to the minimum blood oxygen saturation, and the inflection time (IF) was defined as the half time of the oxygen concentration descending to the minimum. The oxygen consumption (depletion rate) explained the isometric contraction oxygen consumption rate. RESULTS: Our results showed

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that there are no statistical differences on the baseline,ÄStO2 values and IF between two groups. The ÄStO2 values of 25% and 50% contraction for the healthy participants were 21.45% and 21.38%, respectively. Similarly, for the MND patients were 21.40% and 23.57%, respectively. In addition, the IF of 25% and 50% contraction for the healthy participants were 10.06 and 10.78 sec, respectively; similarly, for the MND patients were 11.63 and 9.77 sec. CONCLUSIONS: Our study provided the evidences of no differences on muscle oxygen under low isometric intensity between healthy and MND adults.

P2-E-42 Functional analysis of the stomatognathic system in individuals with multiple sclerosis

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AIM: Multiple sclerosis is one of the major diseases affecting the central or peripheral nervous system. This disease is characterized by a chronic inflammatory process that acts in the destruction of myelin sheaths of the nervous system. The objective of this research was to analyze the effects of multiple sclerosis in the performance of the masticatory muscles. METHODS: This study was previously approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo. Twenty two individuals of both genders, aged 18 to 45 years, were divided into two equal groups: Group MSG, individuals with multiple sclerosis and Group CG, healthy individuals. All individuals were evaluated on the basis of the electromyographic activity of the right and left temporal (RT, LT), right and left masseter (RM, LM), during postural jaw conditions (rest, protrusion, right and left laterality). Surface electromyography was performed using the EMG-Br1 Myosystem®. The values were normalized by the value of the electromyographic signal of maximum dental clenching, harvested by four seconds. The electromyographic means were tabulated and subjected to statistical analysis using t test (SPSS versão 21.0). RESULTS: Normalized electromyographic activity was significant ($p<0.05$) for right laterality: RM= [(MSG = 0.36 ± 0,02), (CG=0,13 ± 0.03)]; LM= [(MSG = 0.29 ± 0,11), (CG=0,14 ± 0.02)] and left laterality RT= [(MSG = 0.36 ± 0,01), (CG=0,07 ± 0.01)]; RM= [(MSG = 0.27 ± 0,06), (CG=0,11 ± 0.02)]; LM= [(MSG = 0.38 ± 0,07), (CG=0,12 ± 0.04)]. CONCLUSION: Based on the results of this research, it can be concluded that individuals with multiple sclerosis showed muscular changes related to the stomatognathic system, especially concerning EMG activity of postural jaw conditions.

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P2-E-43 Midfoot Kinematics During Adult Gait

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AIM: The midfoot segment is a complex structure that provides mobility and stability as motion is transferred from the rearfoot to the forefoot during the gait cycle. Despite its important role, we currently know very little about the mechanics of the midfoot during gait. This is partially due to the difficulties associated with quantifying midfoot mechanics. As a result, this segment is often excluded from kinematic models and is often assumed to act synergistically with the forefoot. However, this assumption has not been adequately tested. To further our understanding of midfoot mechanics in typical and atypical populations, this study quantified the 3D kinematics of the midfoot during walking at various speeds in adults. METHOD: Twenty-one adults (11 female, 12 male) aged 18 to 28 years were recruited to participate in the study (age = 23.0±2.6 years; height = 1.73±0.1 m; weight = 72.1±10.1 kg). Participants were asked to perform gait trials at 5 different walking speeds. A 12-camera Vicon T160 motion capture system (Oxford Metrics Group, UK), sampling at 100 Hz, was used to track the three-dimensional trajectories of 34 reflective markers placed on the participant. The rigid body model consisted of five segments: 1) the shank, 2) the total foot (single rigid segment), 3) the calcaneus, 4) the midfoot, and 5) the forefoot. Euler angle data was analyzed using custom software created in Matlab (Mathworks, Inc, USA). An ANOVA and post hoc analyses were conducted using SPSS (IBM, USA) to test for significant differences in maximum relative joint angles across 5 walking speeds (very slow, slow, free speed, fast, and very fast). RESULTS: The motion of the midfoot relative to the calcaneus is relatively small across all walking speeds in adults (Figure 1). A similar pattern of motion was exhibited between the forefoot and calcaneus. Range of motion between the midfoot and forefoot was greatest in the sagittal plane and reached a mean peak of 6.4°±1.5 during the very fast walking speed. Small but significant changes ($p<0.002$) in mean maximum plantarflexion of the midfoot relative to the calcaneus were found across walking speeds. The maximum plantarflexion of the midfoot-calcaneus increased from 8.8°±2.3 at very slow to 10.52°±3.9 at very fast walking speeds. The forefoot with respect to the calcaneus demonstrated similar results. CONCLUSION: Synergistic and differential movement of the midfoot relative to other segments suggests that this segment demonstrates small and complex motions during gait, which should not be ignored. Movement of the midfoot also changes as a function of walking speed.

P2-E-44 The strategies on turning while walking after stroke

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Back ground and Aim Though turning has a high risk of falling among stroke patients, previously there has been little research on turning undertaken using visual cues. The turning in the daily life is difficult to reproduce under the experimental environment. A method that can more clearly and continuously detect the onset of turning while walking, is necessary. The aim of this study is to correctly analyze the strategy for the onset of turning while walking after stroke. Methods Eight patients with a hemiparesis due to a stroke (66.1 ± 10.2 years, left and right hemisphere lesions; 5/3) participated in this study. All patients can walk independently without a cane. After walking 4-5m, participants were visually cued to turn 90° to the left or right. Visual cues were activated in the non-paretic or paretic foot-contact (stance) by using a foot switch. With the stance and the direction, the turning tasks were classified as the ipsilateral turning (non-paretic stance/non-paretic direction: NPS/NPD, paretic stance /paretic direction: PS/PD) or the contralateral turning (NPS/PD, PS/NPD).The movement of Head and Pelvis in response to the turning cue were examined by using an inertial sensor. A paired t-test or Wilcoxon rank test was used to the each turning reaction times. Results Head movement started to turn before Pelvis movement in both the ipsilateral turning ($P<0.05$) and the contralateral turning ($P<0.01$). The mean reaction times were as follows; NPS/NPD: Head=433.8±63.9msec and Pelvis= 547.5±47.6msec, PS/PD: Head=451.3±97.2msec and Pelvis=563.3±101.8msec, NPS/PD: Head=390.4±56.2msec and Pelvis=635.0±82.7msec, PS/NPD: Head=424.2±69.5msec and Pelvis=615.4±79.3msec. Conclusions This study analyzed more clearly the timing of the onset of turning while walking by using the foot switch. The sequence of body segments were observed in both the ipsilateral and the contralateral turning. And this results suggested that stroke patients had a slower Pelvis movement in the contralateral turning than the ipsilateral turning. The strategies of turning are due to the difference in the direction and the characteristics of a hemiparesis.

P2-H-45 Muscle synergies underlying sit-to-stand tasks and their relationship with kinematic characteristics

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BACKGROUND AND AIM: Standing from a seated position is crucial for human activities because standing up on their feet is a vital prerequisite for bipedal walking. In a sit-to-stand (STS) task, the body's center of mass has to lift and balance itself on narrow feet. Therefore, a

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STS task has unique kinematic characteristics that start with trunk flexion and end with whole body extension. The muscle activities involved in this kinematics are also assumed to be patterned (muscle synergy). However, because not exactly the same kinematic strategies are used to achieve a STS task, we hypothesize that muscle synergies are of various kinds. Thus, the purpose of this study was to investigate various muscle synergies, and to understand how healthy adults achieve STS tasks.
METHODS: In this experiment, 7 healthy male subjects were asked to stand up 7 times in each of the 2 speed conditions, comfortable and fast. A surface electromyogram (EMG) device (NORAXON corp.) was used to collect the muscle activities data from 8 muscles (tibialis anterior [TA], soleus [SOL], gastrocnemius, vastus lateralis, rectus femoris, semitendinosus, and gluteus maximus). Subsequently, a non-negative matrix factorization algorithm was applied to the EMG data for extracting muscle synergies. Correlation of the muscle synergies among the subjects and their speed conditions were assessed using the cosine similarity. A motion capture system (Vicon Corp.) was used to acquire kinematics information of the subject. Subsequently, the following parameters were calculated: 1) the difference of peak timing between the pelvis and shank angles of inclination and 2) the direction of sagittal ground reaction force when the muscle synergies are activated to the maximum (θ).
RESULTS: Two muscle synergies were extracted from every subject and speed condition. One synergy was activated primarily in the seat-off phase, and the other was activated primarily in the extension phase (S_{MID}, S_{LAT}, respectively). The correlation coefficients were high in S_{LAT} (r = 0.83), but not so much in S_{MID} (r = 0.77). Many subjects highly inclined their pelvis after inclination of the shank (12.90 ± 15.47 t/T); however, the relationship between the pelvis and shank was reversed in some subjects(-7.50 ± 7.13 t/T). The S_{MID} of the former subjects was dominated mainly by the TA and to a small extent by the SOL. In contrast, the S_{MID} of the latter subjects consisted of similar activation level of the TA and SOL. For all the subjects and conditions, θ was nearly vertical(-4.61 ± 2.48 °).
CONCLUSIONS: Our results show that muscle synergies underlying STS tasks were modulated by individual kinematic characteristics. These synergies were independent of the direction of the ground reaction force, unlike reported in previous studies on standing tasks. This suggests that muscle synergies underlying STS tasks have a relationship with segmental dynamics.

P2-H-46 The importance of feed-forward control in posture stability

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BACKGROUND AND AIM: The center of pressure (COP) trajectory is always represented by two variables (x and y coordinates, the magnitude and direction of a vector). We proposed a new method of representing the COP sway velocity with one variable. We defined the variable by using the COP vectors to calculate the area of the circularsector. This concept is both similar to "stabilogram diffusion analysis (SDA)" (Collins and De Luca, 1993) and Nagano's analysis (Nagano et al., 2010). SDA calculates the average distance traveled by the COP within a certain time interval, and Nagano's analysis evaluates the directional change of COP sway by calculating the cosine of the vectors. While, both SDA and Nagano's analysis require two variables to generate a stabilogram, the proposed method can do it with only one variable which includes the amount of comprehensive change in the magnitude and direction of the COP sway. We named the new method "stabilogram fan-shaped analysis (SFA)". The purpose of this study was to investigate the influences of feed-forward and feed-back control on posture stability using SFA and Nagano's analysis. METHODS: Nine healthy young subjects participated in this study. Stabilographic examinations were performed during the trials with both open and closed eyes on a force platform. The time-series data for the COP were acquired at 100 Hz with a 30-s sampling time. Using the SFA method, the area of the circular sector was defined by the velocity vector after a certain time interval (ΔT) was calculated. The area was then averaged over the number of time intervals that made up the COP time series. This process was repeated for increasing values of ΔT. A plot of the mean area of the circular sector versus ΔT was called an SFA plot. The FFratio(Feed-Forward ratio) was defined as the ratio of the integrated value of the SFA plot up to 0.10 s to the integrated value up to 3.0 s. Additionally, the FBratio(Feed-Back ratio) was defined as the ratio of the integrated value of an SFA plot from 0.20 s to 0.70 s to the integrated value up to 3.0 s. RESULTS: The FFratio and the directional change of COP sway in the feed-forward phase was significantly larger for the open eyes condition. This implies that the COP sway for the open eyes condition displayed a random-like nature as one would expect from predictive postural control in the feed-forward phase. Meanwhile, there was no significant difference for either conditions with regard to the FBratio and the directional change of the COP sway in the feed-back phase. CONCLUSIONS: These results suggest that feed-forward control rather than feed-back control play an important role in posture stability.

P2-H-47 Threat of perturbation effects on anticipatory postural control

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BACKGROUND AND AIM: When individuals are required to perform a voluntary movement at the edge of an elevated surface, the amplitude and rate of the required anticipatory postural adjustment (APA) is reduced (Adkin et al., 2002; Yiou et al., 2011). While this change

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may be attributed to a threat-related response (i.e., fear, anxiety and arousal) to standing at height, it is possible that the altered pattern reflects a strategy where individuals minimize body movement towards the edge of the surface to prevent a fall. In order to differentiate between these factors, this study introduced a different form of postural threat, specifically a potential perturbation to the body, to examine how this threat affects an individual's ability to perform a voluntary heel raise task. METHODS: Fourteen young adults (21±1 y) stood on a force plate while they completed two experimental conditions. For the low threat condition, participants were provided an auditory warning tone followed 2-12 s later by a go tone. Upon presentation of the go tone, participants were required to perform a heel raise as rapidly as possible. For the high threat condition, participants were provided the same warning tone. However, 2-12 s later, participants either heard the same go tone, for which they were required to perform a heel raise, or experienced a support surface translation in the medio-lateral direction (25 cm displacement, 0.9 m/s velocity, 1.7 m/s/s acceleration) that disturbed their balance. Participants were not required to perform a heel raise when they experienced the surface translation. Performance on each heel raise trial was quantified by measurement of the tibialis anterior (TA) and soleus (SOL) electromyographic (EMG) onset latencies and amplitudes, as well as the peak backward and forward displacement of the center of pressure (COP). At the end of each condition, participants reported their perceived fear and anxiety to establish the amount of postural threat they experienced. RESULTS: Participants reported a greater level of fear and anxiety during the high compared to the low threat condition ($p<0.001$), indicating that postural threat was elicited by introducing the possibility of a surface translation. Consequently, participants exhibited larger APAs, as reflected by a 24% ($p=0.01$) larger backward COP displacement and a 39% ($p=0.03$) greater TA EMG amplitude during the high compared to the low threat condition. For the forward and upward movement of the heel raise, a 20 ms earlier ($p=0.05$) and 16% larger ($p=0.03$) SOL EMG activation was observed during the high compared to the low threat condition. CONCLUSIONS: Our results using a threat of perturbation contrast with previous findings of reduced APAs and EMG activity when the postural threat was evoked through changes in surface height. This suggests that the characteristics of the postural threat must be considered to isolate the effects of threat on anticipatory and voluntary movement control.

P2-H-48 Age-related Differences in Neuromuscular and Morphological Characteristics of Plantar Flexors

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INTRODUCTION: Aging is related to the loss of muscle structure and function. Muscle strength and power are important determinants of daily living, functional ability, and independence. They are influenced by neuromuscular and morphological characteristics, including the rate of force development (RFD), muscle activation (MA), muscle thickness (MT), pennation angle (PA), fascicle length (FL), and muscle-tendon junction (MTJ). Especially, RFD is defined as the ability to produce large amounts of force rapidly which are directly related to muscle strength and power. AIM: The purpose of this study was to compare the differences of strength and power properties of plantar flexors in younger and older healthy women. METHODS: Fifteen younger females (YG, age: 20.4±0.6 yrs, height: 164.8±4.3 cm, weight: 55.3±5.8 kg) and fifteen older females (OG, age: 66.5±4.3 yrs, height: 153.2±4.9 cm, weight: 57.4±7.4 kg) participated in this study. In order to assess strength and power of the plantar flexors, a custom-built dynamometer, electromyography (Trigno Wireless 8chanel, Delsys, Boston, MA) and Ultrasonography (Aloka, Japan) were used. The subjects performed maximal voluntary isometric ankle plantar flexion at ankle joint angle (10 degree plantarflexion). The rate of force development (RFD), muscle activities (MA) of the lateral and medial gastrocnemius (LG and MG), the soleus (SOL), displacement of muscle-tendon junction (MTJ) and architecture (MT, PA, FL) were examined. Neuromuscular and morphological properties of the plantar flexors were compared between younger and older females. Independent t-test was used to test statistical significance. RESULTS: The rate of force development during fast isometric ankle plantar flexion was found to be significantly different between younger (46.3±14.5 Nm/s) and older (175.2±78.3 Nm/s) females ($p<.05$). The muscle activation of lateral gastrocnemius was found to be significantly different between younger (0.10±0.04) and older (0.07±0.04) females ($p<.05$), but the displacement of lateral gastrocnemius (YG: 1.6±1.2 mm, OG: 1.0±0.4 mm, $p>.05$). The architecture variables of lateral (FL: 11.7±1.7 cm vs 9.6±1.5 cm, MT: 2.9±0.5 cm vs 2.2±0.4 cm) and medial (PA: 18.7±2.6 deg vs 17.0±2.9 deg, FL: 10.4±1.5 cm vs 8.2±1.1 cm, MT: 3.2±0.4 cm vs 2.5±0.4 cm) gastrocnemius and soleus (MT: 2.4±0.4 cm vs 2.0±0.6 cm) were found to be significantly different between younger and older females (YG vs OG, $p<.05$). CONCLUSION: Older females were found to show significantly slowly rising ankle plantar flexion torque values than younger females; which seemed to be largely due to smaller activation of the muscle and muscle size. Suggesting that regular exposure to strength and power training for the maintenance of muscle strength and function for independent life.

P2-H-49 Musculoskeletal Modeling driven by Electromyograms processed via Bayesian Filtering Techniques

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BACKGROUND AND AIM: Understanding healthy or pathological movement necessitates the understanding of the dynamics of the neuro-musculo-skeletal system. A way to do this is that of recording experimental electromyograms (EMGs), extracting estimates of the neural drive to muscles, and drive forward dynamic simulations of the resulting mechanical forces elicited at the musculoskeletal level, i.e. EMG-driven musculoskeletal modeling [1]. This was validated on the ability of predicting inverse dynamics joint torques, in vivo joint contact forces, or joint stiffness. Indirect neural drive estimates are conventionally derived from EMG amplitude. EMGs are demodulated to recover amplitude information proportional to the neural drive, i.e. high-pass filtering, rectification, and low-pass filtering with a priori chosen cut-off frequencies. The resulting linear envelope bandwidth is directly determined by the chosen cut-off frequency. Cut-off frequencies suited for one motor task may not equally well apply for others. Extracting realistic muscle excitations is central for EMG-driven modeling as predicted musculoskeletal forces are largely dependent on the EMG-extracted excitation patterns. METHODS: An alternative to EMG linear filtering is the Bayesian filtering. This has been shown to provide smooth amplitude estimates while preserving reactive dynamics to rapid changes in contraction force [2]. The advantage is that no a priori defined cut-off frequency limits the tracing of rapid dynamic changes in neural drive but instead the Bayes filter is able to dynamically adapt to new force levels online after only few samples of data. In this study we employ a Bayes-Chapman-Kolmogorov filter with different likelihood functions (Laplace and Gauss). Walking and running data were collected from one subject including EMGs from 16 leg muscles, whole-body kinematics and foot-ground reaction forces. RESULTS: Bayes filters generate muscle excitations that enable accurate prediction of joint torques about six degrees of freedom (DOFs) across hip, knee and ankle joints. Across all trials and DOFs, RMSEs between predicted and reference joint torques were 0.16±0.1Nm/Kg (Gauss) and 0.15±0.09Nm/Kg (Laplace). The R2 was 0.82±0.1 (Gauss) and 0.84±0.07 (Laplace). Torques from linearly filtered EMG displayed comparable metrics but lesser capacity in predicting fast torque transitions. CONCLUSIONS: The reliable determination of EMG-dependent musculoskeletal forces will enable understanding the neuro-mechanical interplay underlying in vivo movement function, pathology and recovery and will facilitate the design of personalized neurorehabilitation technologies. [1] Sartori et al., J. Neurophisiol. 114, 2015 [2] Hofmann et al. IEEE TNSRE 2015

P2-H-50 Shear wave speed measurements during isometric contractions of stroke-impaired medial gastrocnemius and tibialis anterior

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Individuals who have had a stroke have limited mobility and altered gait. Although impaired motor control contributes to limited mobility, changes in muscle properties such as architecture and material properties will also influence the force generation and

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transmission. Our previous work has shown, using shear wave (SW) ultrasound elastography, that the passive muscle SW velocity, and indiciation of stiffness, is up to 59% greater in stroke-impaired muscle compared to the contralateral non-paretic muscle. The aim of this study was to build upon this previous work and compare both passive and active muscle in stroke-impaired muscle of the ankle plantarflexor, medial gastrocnemius muscles (MG), and dorsiflexor, tibias anterior (TA), to the contralateral non-paretic muscle. Methods Fifteen stroke survivors participated in this study (age: 58.78 ± 7.34 yrs; height: 1.72 ± 0.08 m; body mass: 85.37 ± 16.55 kg; time post-stroke: 10.65 ± 7.08 yrs.). Subjects were seated upright with their knee in maximum extension and their foot secured to the platform of a dynamometer (System 3 Pro, Biodex Medical Systems, New York) with the ankle positioned at 90 degrees. Subjects performed a series of isometric plantarflexion and dorsiflexion contractions at different activation levels (0, 10, 20, 40, 60% maximum voluntary contraction (MVC) while ankle torque, muscle activity (EMG), and ultrasound images (Aixplorer, SuperSonic Imagine) of the MG and TA muscles were captured in separate trials. Mean SW velocity was calculated from a region of the ultrasound images (12-25 mm by 12mm). A quadratic fit was used to evaluate the relationship between SWS and %MVC. A t-test was used to compare the SWV at rest between the paretic and non-paretic side. SWV values at specific %MVC (10, 20, 40, 60%) were calculated. An AnoVa was used to compare the SWV at the different % MVC levels (quadratic) and non-paretic or paretic side. Results Our main findings show that at rest, there was no significant difference between the SW velocity in paretic MG and TA, compared to the non-paretic, respectively. As muscle activation increased, SW velocity also increased in a quadratic relationship for both muscles. There were no significant differences between the paretic and non-paretic muscles, or between the muscle activation and SWS. Discussion In stroke survivors, it seems that any increased stiffness measured of the passive contractile elements has no contribution to the overall stiffness in active muscle such that contributions to active stiffness, such as short range stiffness which is related to the cross-bridging of actin and myosin filaments. This is contrary to findings from previous experiments done on upper extremity muscles of stroke subjects. We hypothesize that possible explanations for this lack of contribution are linked load sharing and supplemental torque applied by the quadriceps, which will be controlled for during control subject experimentation.

P2-H-51 The interaction of biceps and brachioradialis for the control of elbow flexion and extension movements

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INTRODUCTION:Elbow flexion and extension movements are frequently used in various activities of daily living and require adaption to changes in position, speed, and load of the intended motion. But, how is the control of these movements regulated? From a biomechanical perspective, a muscle could contribute to the overall movement control with a load bearing or a fine-tuning regulating function. The torque of the generated muscular force can either oppose (load bearing function) or be in line (fine-tuning function) with the torque of the movement of the limb. Thus, the aim of this work was to analyze the control strategy of biceps and brachioradialis during a load bearing and a fine-tuning function. METHODS:The surface electromyogram of biceps, brachioradialis and triceps were examined in 15 healthy subjects. With the help of a pulley machine and a visual feedback, dynamic flexion and extension movements of the elbow with different combinations of contraction levels and angular velocities were performed. Thereby the measurements were conducted in two configurations, where the torque due to an external load opposes once the rotational direction of the elbow flexion (movement further referred to active flexion) and once the rotational direction of the elbow extension (movement further referred to active extension). RESULTS:The results showed that during active flexion, when the flexors bear the load, the biceps and brachioradialis act synergistically with a similar muscular activation for all movement conditions. In contrast during active extension, when both flexors contain a fine-tuning function, the muscular activation of both flexors varies. For low external loads the biceps showed highest activation for angular velocities below 50°/s and joint angles above 100°, while the brachioradialis showed highest activation for high angular velocities above 100°/s and joint angles below 50°. For higher external loads the brachioradialis showed no adaptions to different joint angles, while the biceps showed no adaptions to the different angular velocities for flexion angles exceeding 65°. CONCLUSION:The interaction of biceps and brachioradialis is differently expressed for a load bearing or a fine-tuning function. For active flexion movements, where both flexors contain a load bearing function, they act synergistically with a similar muscular activation for all combinations of joint angle, angular velocities and external loads. In contrast, for active extension movements, where the biceps and brachioradialis comprise a fine-tuning function, the muscular activation of both flexors is adapted differently depending on the movement task. The results were linked to the fiber type composition and innervation of both muscles and led to the conclusion that during fine- tuning of the movement, the biceps contributes to the control of different loads, while the brachioradialis contributes to the control of different angular velocities of the performed movement.

P2-H-52 Center of pressure mean velocity predicts single limb stance time in experts and novices

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BACKGROUND AND AIM: Balance tests, such as the BESS test, are used to diagnose concussions and assess safe return to activity. However, they often exhibit ceiling effects,making it difficult to detect mild impairments. Such ceiling effects are more pronounced when testing skilled populations with mild impairments, such as concussed athletes. Our goal is to overcome these ceiling effects by developing a balance test that is sufficiently difficult to identify small differences in balance performance.We hypothesize that behaviors challenging enough to elicit failures can be used to discriminate between expert and novice balance performance. Similarly, Sawers and Ting 2015 showed differences between novices and experts in a challenging beam walking task. Standing balance tasks may be more practical to measure in space-constrained clinical settings. Therefore, as a first step towards developing a more sensitive balance test to distinguish between impaired and unimpaired athletes, we compared balance in ballet dancers (experts) and healthy non-dancers (novices). Our objectives were to: (1) determine if time standing during eyes-closed single-limb stance (SLS) and center of pressure (CoP) metrics distinguished experts from novices, and (2) determine if CoP metrics predict when a loss of balance will occur. METHODS: We calculated mean CoP velocity from six-axis ground reaction forces in 10 professional ballet dancers and 17 novices. Subjects stood on one leg with their eyes closed for 30 seconds or until they lost their balance. Five trials per leg were collected in a randomized order. In trials where a balance failure occurred, the CoP time series was truncated before the loss of balance. We also tested whether mean CoP velocity over different portions of a trial could predict time standing in a trial. RESULTS: Experts maintained balance longer than novices (22 ± 11, 18 ± 12 s; p=0.01) and had lower mean CoP velocities (74 ± 230, 190 ± 1700 cm/s; p=0.03). Mean velocity over the entire trial was correlated to time standing in experts and novices (log-linear fit, R=0.96). Moreover, mean velocity in the first seven seconds was sufficient to predict a loss of balance (R = 0.90). CONCLUSIONS: Despite group differences between experts and novices in mean CoP velocity and time standing during eyes-closed SLS, skill level was not a factor in the predictive relationship between mean CoP velocity and time standing. Moreover, mean CoP velocity was consistent over the entire duration of a trial and could be computed over just a the first few seconds from any portion of each a trial to predict time standing. Our results suggest that eyes-closed SLS may be a simple and robust test of balance ability that is of sufficient difficulty to detect differences between healthy and impaired athletes.

P2-I-54 New Mechanomyogram / Electromyogram Hybrid Transducer for evaluation of muscle contraction during cycling-wheelchair exercise

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BACKGROUND AND AIM : The simultaneous evaluation of muscle contraction and performance with both EMG (electromyogram) and MMG (mechanomyogram) is necessary. The authors previously proposed a wireless displacement-MMG (d-MMG) transducer with two electromyogram (EMG) electrodes. In this study, the new MMG/EMG hybrid transducer with a single supporting leg has been developed and it was easier to attach it on the skin surface. This transducer was applied to evaluate the muscle contraction during cycling-wheelchair exercise. METHODS : The new developed MMG/EMG hybrid transducer (30 mm long × 30 mm wide × 14 mm high, 8.7 g) is composed of a small photo-reflector, two EMG electrodes and an amplifier. The single supporting leg of transducer was firmly placed along curvature of the skin/muscle surface. The resolution of d-MMG measurement and power consumption of the transducer were improved. The transducer was applied to exercise with a cycling-wheelchair (Profund, TESS, Japan). The healthy subject pedaled the wheelchair once in two seconds for ten seconds. The d-MMG and EMG were measured on the muscle surface (RF: rectus femoris, VM: vastus medialis, TA: tibialis anterior, GC: gastrocnemius) of both legs. It was possible for a single paralytic to pedal this cycling-wheelchair easily by himself. In order to increase the pedaling load, the wheelchair pulled a load (heavy: 15kg, light: 10kg). The pedaling period was analyzed by dividing into four phases as the starting point of the maximum flexion angle of the knee. During a subject's pedaling, we measured the d-MMG, the integrated EMG (EMG-ARV) and the crank angle of the wheelchair. The acceleration MMG (MMGacc) was calculated by the second differential calculus of d-MMG. The experiment was performed with approval of the ethic committee of Okayama University. RESULTS : Figure shows the MMGacc and EMG-ARV during cycling-wheelchair exercise with a heavy load (left) and with a light load (right) for the crank angle phase1-4. The sine wave in the figure indicates the crank angle and the phase 1 and 2 mean pushing-down the crank and extending the knee. The phase 3 and 4 mean pulling-up the crank and flexing the knee. In the phase 1-2, the EMG and MMGacc of RF muscle increased but those of VM muscle decreased. As the MMGacc of TA muscle increased and that of GC muscle decreased, the TA muscle dorsiflexed the pedal with GC muscle antagonistically. In the phase 3-4, the EMG and MMGacc of TA and GC muscle increased. The subject drove the pedal by torque, because TA and GC muscle co-worked together and fixed his ankle. CONCLUSIONS : In this study, the muscle contraction was evaluated by the MMG/EMG hybrid transducer during cycling-wheelchair exercise with various pedaling loads. In future, this transducer could be applied successfully in the rehabilitation field. ACKNOWLEDGEMENT : This research was partially supported by a Grant-in-aids for Scientific Research (25350529) from JSPS.

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P2-I-55 Evaluation of Muscle Contraction using 5×5 MMG Array Sensor, 64 Channel sEMG Multichannel Sensor and Ultrasonic Image Equipment

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BACKGROUND AND AIM : The mechanomyogram (MMG) is a muscle vibration caused by muscle contraction. The authors previously developed a 5×5 multichannel displacement-MMG (d-MMG) array sensor, which was composed of 25 photo-reflectors to measure the displacement to a skin surface. In this study, using this array sensor, we have drawn two-dimensional d-MMG map in the range of 40 mm × 40 mm. The 64-channel surface EMG (sEMG) and a pennate angle of the vastus lateralis (VL) muscle were measured during voluntary isometric contraction. METHODS : The VL muscle of healthy subject's right leg during isometric contraction with open kinetic chain was examined and his knee joint was fixed at 65° of flexion angle. The isometric contraction was of 10-100% maximum voluntary contraction (MVC) every 10%. The d-MMG array sensor and the 64 sEMG electrodes were placed on the VL muscle (distal third of the line which links the lateral epicondyle to the greater trochanter). The EMG electrodes (EMG-USB1 64, OT Bioelettronica, Italy) were located every 8 mm two-dimensionally and were measured as bipolar electrodes, and the reference electrode was attached on the knee. The pennate angle was also measured at the same point of the VL muscle surface. The subject sat on the seat (GT-330, OG Giken, Japan) with his knee at flexion of 65 degrees. The subject made a knee extension for three seconds and the averaged signals of d-MMG and sEMG were analyzed for a second while the muscle force was stable. The pennate angles of the VL muscle were measured by B-mode echo of the ultrasonic equipment (Xario 200, Toshiba Medical Systems Co., Japan). The experiment was performed with approval of the ethics committee of Okayama University. RESULTS : Figure (a) shows the 5×5 d-MMG mapping on the VL muscle at 10%, 70% and 100%MVC. The vertical axis indicates the displacement [mm] from the muscle surface. The bigger deformation points (yellow and brown) were close to the internal and distal side. Figure (b) shows the two-dimensional color mapping of 64-channel sEMG and the blue points of the measuring area were identified with an innervation zone of the VL muscle. The measured area of d-MMG array sensor was corresponding to the center of the 64-channel sEMG mapping. The points of bigger sEMG (red) were also found in the internal and distal site and were similar to those of d-MMG mapping. According to the results of pennate angle measurement, the angles increased gradually when the %MVC of the VL muscle increased (Figure (c)). CONCLUSIONS : The two-dimensional d-MMG mapping were drawn using the 5×5 multichannel d-MMG array transducer during isometric contraction. The multichannel sEMG mapping was also drawn using the 64 channel sEMG array sensor. And the increase of pennate angles showed the increase of the volume of the VL muscle. ACKNOWLEDGEMENT : This research was partially supported by a Gant-in-aids for Scientific Research (25350529) from JSPS.

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P2-I-56 Inter-rater reliability of kinematic assessment of upper extremity movement based on inertial sensors ? A pilot study

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Background & aim: Analysis of lower limb movements is well established in clinical research and applications, mostly in form of gait analysis. Reliable and objective assessment of the upper extremity function is important in several neurological and musculoskeletal disorders, i.e. stroke, Parkinson?s disease and shoulder instability. In this study, the aim was to analyse inter-rater reliability of kinematical measures for two tests that are commonly used to assess hand and arm function after a stroke; Finger-To-Nose and Drink-from-Glass test. Methods: Twenty healthy volunteers (39.8 ± 11.6 years, 7 females, height 1.74 ± 0.09m) in the study. In the Finger-To-Nose test, the persons were asked to touch their nose with the index finger and thereafter return the hand to the initial position on the table in front of him/her at self selected speed (n=10). For the Drink-from-Glass test the glass was placed along the midline at a distance of 7, 30 or 50 cm in front of the subject. The persons were asked to lift the glass, take a sip and then put the glass down and return to the initial position at self-selected speed (n=10 per distance). The test session was performed with two different raters, in randomized order, with approximately five minutes rest in between. A portable movement analysis system with five tri-axial inertial sensors, 128 Hz sampling frequency, was used for data collection. Two sensors were placed on each forearm, two on the upper arms, and one on the xiphoid process. The kinematic and temporal measures calculated for each repetition were (i) Elbow Range Of Motion (ROM) in flexion-extension and internal-external rotation, (ii) Shoulder ROM in flexion/extension, abduction/adduction and internal/external rotation and (iii) Cycle time. ICC was calculated between the raters. Results: For Finger-To-Nose (n=386), Inter-rater ICC was excellent concerning Cycle time (0.83) and shoulder ROM in internal-external rotation (0.77). It was fair to good for elbow ROM in internal-external rotation and shoulder ROM in flexion-extension and abduction-adduction directions (0.63, 0.75 and 0.73 respectively), and poor for the elbow ROM in internal-external rotation (0.20). For the Drink-from-Glass test ICC was excellent in all cases (0.81-0.89) but elbow ROM in internal-external rotation (0.29). Conclusions: In this study we aimed at analysing the inter-rater reliability for two tests commonly used in the clinical setting. The inter-rater reliability was high for all selected kinematic outcome measures, except for elbow internal-external rotation. The elbow rotation is known to be more sensitive to errors in sensor placement which was confirmed in this study. The high reliability was probably related to the strictly followed protocol when mounting the sensors, and standardisation of verbally recorded instructions. This shows that inertial sensors could give a valuable contribution to clinical evaluations of arm function.

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P2-I-57 Reliability of helical axis parameters during glonohumeral rotation

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Shoulder instability (SI) is a common pathology defined as symptomatic laxity of the glenohumeral joint. It can limit the shoulder function especially in athlete's who perform overhead gestures, or in workers doing prolonged overhead activities such as painters, storekeepers or in throwing activities. The instability of the shoulder can lead to changes in arthrokinematics of the glenohumeral joint during overhead shoulder movements. The SI diagnosis is based in history and physical examination that included specific provocative tests. There is currently lack of diagnostic procedures aimed to quantify the shoulder instability arthrokinematics. The aim of this study was to evaluate the reliability of finite helical axis (FHA) parameters in the analysis of shoulder rotation. Nineteen healthy subjects (7 males, 12 females, age: 23.2±2.7 years) participated in the experiment. Shoulder kinematics was measured by means of an optoelectric motion capture system (Optitrack) including six infrared cameras. The subjects were sitting on a chair with arm abducted 90 degrees laterally. The arm was fixed in a light wooden frame with velcro straps in order to keep the elbow angle at 90 degrees flexion. The subjects were asked to perform two series of ten shoulder internal and external full range rotations. The two series of movements were separated by two minutes of rest without removing the wooden frame. The protocol was repeated for both arms in randomized order. 3D data were sampled at 120 Hz. Side dominance was asked to the subjects resulting in two left dominant subjects. The data were divided in dominant and non-dominant side in order to evaluate differences in shoulder stability analysis between the two sides. The shoulder rotations were analysed with the FHA technique, using angles of 10 degrees to compute each FHA. The dispersion of the FHA for each of the four conditions was computed using the minimum convex hull (CH) and mean angle (MA). The convex hull area was also computed in the intersection of the vertical plane at the level of the Acromion. The intraclass correlation coefficient (ICC) minimum detectable change and standard error of the means were computed for CH, MA and range of movement (RoM) in both arms. The table summarizes the results of the reliability analysis. The reliability of the helical axis parameters was excellent for both sides. Further investigations are needed to establish the clinical relevance of this technique in patients with SI. Table: Summary of the reliability parameters. ICC, confidence interval (95%) upper and lower bounds, standard error of the measurement (SEM) and minimum detectable change (MDC) are shown for the four variables analysed.

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P2-I-58 Development of Flexible Microneedle Electrodes for Recording of Surface EMG

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BACKGROUND AND AIM Accurate biopotential measurement is important in providing electrophysiological information. Wet electrodes, such as Ag/AgCl electrodes used in surface EMG, ECG and EEG, utilise electrolytic gel to increase conductivity which is limited by a high skin contact impedance. However, associated problems include drying of gel [1], motion artefacts, electro-mechanical instability [2] and perspiration [3]. Alternative electrodes include dry electrodes and dry active electrodes incorporating amplification at the site of signal detection. However these also display sensitivity to motion and are prone to shift during movement [1, 4]. Microneedle electrodes potentially offer an improved means of recording sEMG. Their microscale protrusions may overcome the high impedance of the stratum corneum while not activating pain receptors. Microneedles may also provide mechanical stability during dynamic activity. The limited microneedle electrodes proposed are typically rigid, not conducive to form and constitute a single electrically connected electrode [5]. The aim of this project is to develop flexible microneedle electrodes (FMEs) to overcome the limitations of conventional electrodes. By electrically isolating each individual microneedle, the FME will act as an array with high spatial selectivity. METHODS Microneedle arrays were designed and printed using a 3D stereolithographic (SLA) printer (Ember, Autodesk) and UV-curable polymer (Standard Clear Photopolymer Resin PR48, Autodesk). Design inputs, including microneedle height, base diameter and inter-microneedle distance are easily adjustable for parametric studies (e.g. 400μm ht., 214μm base dia., 1mm pitch). These were compared with microneedle electrodes fabricated using drawing lithography. A hard plastic substrate containing cavities was filled with an uncured polymer. A drawing plate containing micropillars was dipped into the polymer-filled holes and raised upward, drawing the polymer up due to adhesion forces, thereby creating microneedle structures. The polymer was exposed to UV-light for curing. RESULTS Both techniques resulted in the formation of microneedle structures. While 3D SLA created a single microneedle electrode, the microneedle tips themselves were not as sharp as those manufactured using drawing lithography tips. CONCLUSION Both 3D SLA and drawing lithography offer promise in prototyping conductive microneedle EMG electrodes. While 3D SLA allows greater freedom in design, drawing lithography tips tend to be sharper. Repeatability of the drawing lithography method warrants further investigation. Currently the incorporation of conductive fillers and electroplating is being optimised for EMG signal detection for functional assessment. REFERENCES [1]Forvi et al, Sens. Act., A Phys, 2012 [2]Roy et al, Med Biol Eng Comput, 2007 [3]Abdoli-Eramaki et al, J Electromyogr Kinesiol, 2012 [4]Daley et a. , J Electromyogr Kinesiol, 2012 [5]O'Mahony et al, Sens. Act., A Phys, 2012

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P2-I-59 Evaluation of shoulder rotation axis during three different tasks

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The term shoulder instability refers to a clinical condition in which soft-tissue or bony impairments and rotator cuff imbalances may lead the humeral head to a sublux or dislocate from the glenoid fossa. The rotator cuff and shoulder ligaments stabilizes the glenohumeral joint and limits the humeral head translations They play an important role in maintaining the normal/correct humeral head position in the glenoid fossa especially during abduction and external rotation of the shoulder. The aim of the present study was to investigate the behaviour of finite helical axis (FHA) during shoulder rotations in three different conditions, and to observe how a mechanical constrain affects the shoulder stability. Nineteen healthy subjects (7 males, 12 females, age: 23.2±2.7 years) participated in the experiment. Shoulder kinematics was measured by means of an optoelectric motion capture system (Optitrack) including six infrared cameras. An additional videocamera was positioned behind the subject and used to provide a visual feedback of arm position. The subjects were sitting on a chair with arm abducted 90 degrees laterally and (see figure). The arm was fixed in a light wooden frame with velcro straps in order to keep the elbow angle at 90 degrees flexion. The subjects were asked to perform three series of ten shoulder inward and outward full range rotations. The three series of movements were performed in the following conditions: 1) eyes closed 2) visual feedback of the camera showed on a screen in front of the subjects 3) arm frame locked to a spherical joint on a wooden support. The protocol was repeated for both arms in randomized order. 3D data were sampled at 120 Hz. The shoulder rotations were analysed with the FHA technique, using angles of 10 degrees to compute each FHA. The dispersion of the FHA for each of the four conditions was computed using the minimum convex hull (CH) and mean angle (MA). In addition the range of movement (RoM) of the shoulder was measured for each of the three conditions. The comparison between dominant and non-dominant arm showed slightly although not significant lower CH area and lower mean angles for the dominant arm. The visual feedback condition showed no difference compared to the condition with eyes closed in both arms. A slightly significant higher CH area and significant lower mean angle (1-way ANOVA, $P<0.01$) were observed in the condition with constrain compared to the other conditions for both arms. The FHA technique can be used to quantify the stability of shoulder during internal and external rotations. Further research to explore the association between the helical axis dispersion and the clinical features of shoulder instability is needed. Figure. Subject position during the internal and external rotations of the shoulder. The helical axes are shown for the two conditions: visual feedback and mechanical constrain. As expected the FHA are passing through the mechanical constrain when present.

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P2-I-60 Automatic Image Processing of Ultrasound Elastography for Obtaining Muscle Shear Modulus by Removing Connective Tissue Data

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BACKGROUND AND AIM: Surface electromyography (EMG) has widely been used for estimating muscle force as a non-invasive and inexpensive method. As its limitation, EMG measurements are variable and susceptible to crosstalk from surrounding muscles, particularly on body segments where there are several small, closely packed muscles with overlapping function, such as in the forearm. Muscle shear modulus measured with Ultrasound Shear-Wave Elastography (USSWE) appears to be advantageous in assessing mechanical activity/properties of a specific muscle because it allows for isolated measurement and direct assessment of mechanical properties. The current analysis of USSWE videos for muscle shear modulus is to calculate the spatial average of shear modulus across the manually selected region of interest, including connective tissues. As connective tissues are stiffer than the surrounding muscle tissues, the inclusion of connective tissue areas in an image is expected to skew the average shear modulus toward higher values. The purpose of the study was to develop and assess an automatic image-processing algorithm for analyzing USSWE videos for obtaining shear modulus of contractile muscle tissues without the contamination of non-contractile connective tissues. METHODS: USSWE videos were recorded from 11 male subjects (age: 21.3 ± 0.9 years (mean ± SD); range: 20-23 years). Subjects grasped the handle of a robotic manipulator with the right hand. Subjects were asked to hold a specified arm posture by co-contracting arm muscles while the robot applied multiaxial forces and torques to their hand. Three 10 second trials of thirteen loading conditions were performed. USSWE videos were captured from triceps longus (TRI) and extensor carpi ulnaris (ECU) at 1 frame/second during these trials. An automatic image-processing algorithm was developed to identify connective tissues in each frame of the USSWE videos in order to isolate and take spatially averaged shear modulus data from the contractile muscle tissues. The algorithm used a set of six optimized parameters to identify bands of connective tissues in a manner that is robust to image quality issues (e.g. poor or uneven image contrast). RESULTS: The skewing of the data, quantified as the standard deviation of the included area of the USSWE data, was by 8% in TRI ($p<0.01$) and by 17% in ECU ($p<0.01$), on average. For both muscles, reductions of more than 50% were seen. CONCLUSION: The study shows that automatic image processing of USSWE in a contracting muscle is possible, and the automatic removal of connective tissues in the analysis can substantially reduce the skewness of muscle shear modulus. Supported by the National

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P2-I-61 Is foot mobility related to age in people with anterior knee pain?

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BACKGROUND AND AIM: Across the lifespan, foot orthoses, or shoe inserts, are commonly used to treat anterior knee pain. Those with greater foot mobility may have a greater likelihood of successful outcome with foot orthoses intervention, compared to those with less mobile feet. However, in healthy cohorts, increasing age is associated with higher soft tissue stiffness and reduced ankle and subtalar joint range of motion. Furthermore, 3D motion analysis has demonstrated that older feet have less midfoot and forefoot mobility during walking. These age-related decreases in foot mobility may reduce success with foot orthoses for older people with anterior knee pain. This study investigated whether older people with anterior knee pain demonstrate lower foot mobility than younger adults with anterior knee pain. METHODS: 194 participants (113 females; mean±SD age 31.9±7.2 years [range 18-50]; height 1.7±0.1 m, weight 74±17 kg) with anterior knee pain (>6 weeks duration) were included. Foot mobility was measured using reliable and valid methods. Arch height and midfoot width were measured at 50% of foot length, in weight bearing (WB) and non-weight bearing (NWB). Arch height mobility was the difference between arch height in NWB and WB, and midfoot width mobility the difference between midfoot width in WB and NWB. Foot mobility magnitude (composite value of vertical and mediolateral midfoot mobility), was calculated as the square root of (arch height mobility %2B midfoot width mobility). K-means cluster analysis classified participants into three homogenous age groups. Univariate analysis of variance (covariates: sex, weight) compared arch height mobility, midfoot width mobility, and foot mobility magnitude between age groups ($p<0.05$). RESULTS: Cluster analysis identified three age groups: 18-29 years (n=70); 30-39 years (n=101); and 40-50 years (n=23). There was a significant main effect of age on arch height mobility ($p<0.001$) and foot mobility magnitude ($p=0.006$). Post-hoc tests revealed that arch height mobility was significantly lower for the 40-50 year group compared to those aged 18-29 years (mean difference 3.3 mm, 95% CI 1.9 to 4.8 mm) and 30-39 years (2.1 mm, 0.7 to 3.5). The 40-50 year group also had significantly lower foot mobility magnitude than those aged 18-29 (2.7 mm, 1 to 4.4) and aged 30-39 (1.6 mm, 0.03 to 3.2). There were no significant main effects for age on midfoot width mobility ($p>0.05$). CONCLUSIONS: People aged 40-50 years with anterior knee pain have lower foot mobility than younger adults. Notably, the difference in arch height mobility exceeds the error associated with the measure. Findings are consistent with kinematic studies showing reduced sagittal plane

mobility with increasing age, provide a simple clinically applicable method of evaluating foot mobility, and have implications for the evaluation and treatment of older people with anterior knee pain.

P2-I-62 Posture of the head and trunk in sitting: quantification of alignment

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BACKGROUND AND AIM: Posture can be assessed either subjectively or objectively. In the literature there are detailed subjective descriptions of 'ideal alignment' in standing but no agreement of an 'ideal seated postural alignment'. The use of radiographs [1, 2], rastersterography , and three-dimensional (3D) motion capture systems have addressed many of the limitations of subjective postural assessments, but are rarely practical in a clinical setting. Video recordings are easily used clinically but also have potential for quantitative analysis of movement. This study used a video based method to generate a numerical definition of postural alignment of the head and trunk in sitting. METHODS: A definition of aligned static sitting posture was agreed in a focus group. Participants (4 male, 4 female, age 27.2±3.25 years) sat upright on a bench. Static and Dynamic trials were recorded simultaneously with a 3D motion capture system and a video camera recording sagittal plane movements. The agreed definition was used to visually identify video frames where posture was aligned. Angles of Head, Neck, Upper, Mid and Lower-Thoracic, Upper and Lower-Lumbar and Pelvis segments were calculated in relation to the absolute coordinate system and used to construct a model of alignment from aligned frames. This clinically based video method has been previously validated against segmental angles calculated from the 3D motion system using the RMSE (ms. under review). RESULTS: For each participant, a segmental model of quantified aligned sitting posture was defined as the set of mean ± SD values from videos. A combined model for the group is shown. RMSE for the Static trials was below 3° and for the Dynamic trials was below 4° in most cases. CONCLUSION: Our study presents a multisegmental numerical model of aligned posture in sitting using a video based method. However, the small sample size is insufficient to generate a universal model. Previous studies [1, 2] have measured angles for the complete thoracic region (36°±12 and 40.60°± 10 respectively). The addition of our mean angles for the UT, MT and LT gives a resultant angle of 45.43°, which is comparable to previous results. For the lumbar region our study revealed much smaller values which is consistent with reports in the literature describing a decreased lordosis curvature while sitting. This multisegmental method of quantification of sitting posture gives greater detail of the spinal profile than previous methods. It has potential as a complementary tool alongside subjective

assessments for patients with a wide variety of pathologies. REFERENCES: [1] Leroux M. 2000. Spine [2] Vialle R. 2005. The Journal of bone and joint surgery. American volume

P2-I-63 Passive and active stiffness of the neck extensor muscles is depth-dependent

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BACKGROUND AND AIM: Muscle stiffness supports joint stability while allowing for a range of movement. Movement limitations and perceived stiffness are major symptoms in chronic neck pain. Understanding the normal regulation of stiffness in the five neck extensor muscles may open new perspectives on altered passive and active muscle properties with chronic neck pain. The aim of the study was to investigate the shear modulus (stiffness) of the five neck extensor muscles during relaxation and graded headlift in healthy individuals. METHODS: Shear-wave elastography of the right neck extensor muscles (trapezius, splenius capitis, semispinalis capitis, semispinalis cervicis and multifidus) was recorded during relaxation and graded isometric head lift, sustained over 6 s. Participants were 4 female and 6 male healthy individuals, aged 22 years (SD 3.2) and free of neck symptoms or previous neck trauma. In prone, participants lifted 1/3, 2/3 or full weight of the head while keeping contact of the forehead with a pressure-sensitive air cushion. Each level of effort was repeated three times, all in a randomized order. Shear modulus within a region of interest in each of the five muscles was extracted over the 3 initial seconds of sustained head lift. Relationships with effort and muscle depth were examined with Spearman correlation (rho). Differences in muscle stiffness were examined using ANOVA. Relationships of shear modulus with effort and muscle depth were estimated with Spearman correlation (rho). Muscle-specific contributions were determined as percentage of total stiffness in each level of effort. RESULTS: Stiffness in relaxation was highest in the multifidus muscle, 14.6 kPa (SD 4.7) $P < 0.002$. Stiffness increased with muscle depth, in relaxation $rho = 0.45$ $P = 0.001$, with head lift $rho > 0.62$ $P < 0.001$. Stiffness of each muscle increased with effort, for multifidus, semispinalis cervicis, semispinalis capitis and splenius capitis $rho > 0.54$ $P < 0.001$, for trapezius $rho = 0.35$ $P = 0.028$. During relaxation and head lift more than 50% of total stiffness were contributed by the multifidus and semispinalis cervicis muscles. CONCLUSIONS: Passive and active stiffness of the neck extensor muscles were organized in a depth-dependant manner with highest contributions from the multifidus and semispinalis cervicis muscles and lowest from trapezius. Passive and active muscle stiffness are biomechanical parameters that provide new insights into synergistic activation patterns. Muscle stiffness can be estimated non-invasively by shear-wave elastography and is likely of clinical relevance.

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P2-I-64 A Preliminary Study on Measurement of Surgery Procedures with Multi-Channel Surface EMG signals

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Backgroud and Aim: The purpose of this study is to examine preliminarily the ability to measure surgical techniques with multi-channel EMG signals. Recently, applications of multi-channel surface EMG signals are discussed on the potentialities in some fields. Surgeons are forced to maintain their posture during surgery and then they often have the trouble on muscle fatigue and decreasing skill performance. In actual, many researchers are concerned in evaluation of muscle fatigue and effort in surgical tasks [1, 2]. Although many publications have reported physiological comparisons during surgical procedures, no study examines measurement of surgery technique itself with EMG signal. Methods: To examine skill of surgery, the subjects were classified into two groups; skill and non-skill groups. The subjects in skill group have surgical experience at least over two years. The subjects in non-skill group have completely no experience on it. During fastening two sutures in a surgical training kit, the multi-channel surface EMG signals on both their forearms are recorded with Myo gesture control armbands (Thalmic labs) each of which have eight bipolar EMG sensors, accelerators, gyroscopes and orientation sensors and can transmit the signals on Bluetooth to the PCs. The subjects were instructed to perform knot-typing tasks six times per a trial. Results: The average times per knot-typing task have significant difference between skill and non-skill groups; 18.4+/-14.5(s) in skill group vs 42.0+/-19.8(s) in non-skill group. Therefore, the surgical skills between the groups are definitely doubtless because of their large time difference. As compared with their root mean squared (RMS) distributions of EMG amplitude on their forearms, the EMG amplitudes of the channels near brachioradialis muscle and extensor digitorum communis muscle on both the arms in both the groups became higher than the EMG amplitudes of the other channels. To evaluate surgical skill quantitatively, we define the parameter of Active Rate which indicates the ratio of RMS values over a threshold in a task. The parameter presents sustainability and concentration of RMS distributions of EMG signals between channels in skill group are distinguishable enough as compared with those in non-skill group. Conclusions: Our results show high possibility of measurement of a surgical technique with multi-channel surface EMG signals. The sustainability and the concentration of the RMS distributions of EMG signals in skill group may contribute to maintain the posture of their forearm to easily control needle holders. In conclusion, multi-channel surface EMG distributions enable us not only to measure the level of surgical technique of knot-typing task but also to support medical education to teach endoscopic

technique. [1] Berguer, R. Et al., Archives of Surgery, 138: 967-970, 2003 [2] Ehlers, Landon et al., Studies in Health Technology and Informatics, 184: 122-8, 2013

P2-I-65 Real-time ultrasound cervical muscle segmentation: with application to monitoring and diagnosis of cervical dystonia

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BACKGROUND AND AIM: Cervical Dystonia (CD) is a prevalent disease affecting thousands of people worldwide; a neurological condition which causes often painful spasticity in one or multiple muscles in the cervical muscle system, currently without a cure, the most effective treatment is to induce muscle paralysis by injecting botulinum toxin into the affected muscle(s). However, clinicians currently have no non-invasive method of targeting and monitoring treatment of deep muscles. Ultrasound has been used to non-invasively image all five bilateral cervical muscle layers, simultaneously. We present a tool, for segmenting those cervical muscles and the spine in real time. METHODS: MRI and ultrasound data were collected from 10 participants (age: 25.0 ± 6.7, male: 5, female: 5). Due to the difficulty obtaining true and accurate muscle boundary labels in our ultrasound images, we have developed a registration approach, in which an expert annotates MRI images (where image-plane markers are present) and then manually registers those annotations to matched ultrasound images. Then, we used shape analysis to create a mean texture, which was then combined with a principal component model of muscle boundaries to create a texture database in principal components shape space. We then compared images in a test set to all database images, resulting in an initial approximate segmentation, followed by refined fitting, to improve the segmentation of the muscle boundaries in real-time. RESULTS: Our technique can currently segment a single image in ≈0.5'' on reasonably cheap computer hardware (i7-4720HQ) and demonstrates an accuracy of over 90%. Fig 1. Muscle feature segmentation visualisation. The graphic shows how the proposed tool provides visualisation of identified cervical muscle features, and also how those features can be represented quantitatively using the component model. a shows the raw ultrasound and b shows the final segmentation. c and d are a vector plot visualisation of the two main components of variance (2 and 9, respectively) - where the blue contours show the shape the component, and the arrows show angle of deviation (i.e. originates at the mean shape, and ends at the component shape - i.e. the major differences of a person's neck from a population). The bar plot (e) shows the absolute magnitude of the components (scaled), where the colour represents the sign (red = negative). CONCLUSIONS: We have shown that it is possible to obtain reliable quantitative descriptions of the anatomical features of a person's muscles in real time. We provide a tool in which clinicians and/or patients can use cervical muscle

visualisations to interpret features, which can be recorded for group and longitudinal investigations.

P2-I-66 Addition of a verbal dual task results in reduced right arm swing while walking and men are more susceptible

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BACKGROUND AND AIM: Arm swing asymmetry during walking increases when a cognitive dual task is introduced and older individuals are more susceptible to this effect. The characteristics and mechanism of this asymmetry shift under cognitive load are unclear. METHODS: Eighty-three healthy subjects (three age groups; 18-39, 40-59 and 60-80) walked on a treadmill at a comfortable walking speed while performing a congruent (CS) and incongruent Stroop (IS) word/colour discrimination task. Gait parameters, including an index of arm swing asymmetry (ASI) based on 3D kinematic wrist trajectory lengths, were recorded. A positive ASI indicates proportionally larger arm swing amplitudes on the left and vice versa. Participants also completed a lateral preference inventory questionnaire (Coren 1979). Trial means of gait parameters were analysed using a linear mixed model with post-hoc t-tests. RESULTS: Compared to normal walking (NW), ASI values increase significantly during both dual-task conditions in the 40-59 age group (NW: -0.28±2.03, CS: 5.87±3.38, IS: 9.19±3.31; p=≤0.048) and in both tasks in older adults (NW: -0.68±2.07, CS: 8.31±3.70, IS: 15.16±3.80; p≤0.009) compared to NW. In adults over 60, this shift was driven by significantly reduced wrist trajectories (CS: -13.1%, IS: -22.1%; p≤0.049) and maximal shoulder anteversion (mean±SD; NW: 4.35±10.07o, CS: 1.21±10.35o, IS: -0.54±11.62o; p≤0.032) under both dual-task conditions. In this older group, right maximal elbow flexion also reduced significantly between the NW and IS conditions (NW: 53.69±11.49o, IS: 48.34±8.08o; p = 0.012). No changes were seen on the left. A sub-analysis showed that males in all age groups exhibited significant, positive shifts in ASI in the IS task, while a similar effect was only seen in women over 60. There were no correlations between the degree of behavioural lateralisation and change in ASI under cognitive load. CONCLUSIONS: These findings suggest that human arm swing is at least partially generated by cortical inputs which are susceptible to interference from concomitant cognitive tasks. In men and older women, increased cognitive load during the primarily verbal, predominantly left hemisphere Stroop task causes a reduction in arm swing on the right. This paucity of swing amplitude is characterised by decreased flexion at the shoulder and elbow with preserved extension, consistent with previous findings that the upper limb flexors are under more direct supraspinal control. Females appear to be resistant to this effect until old age. Whether this

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is related to dual-task performance strategies or a tendency for females to be less strongly lateralised is unclear, although lateralisation did not predict the degree of arm swing attenuation. Using a similar approach to analyse arm swing under differing cognitive loads in patients with Parkinson's disease, subcortical stroke and spinal cord injury may permit further insights into the control of arm movements in human locomotion.

P2-J -67 Change in the lateral axis of high-heeled shoes on the frontal plane

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BACKGROUND AND AIM: High-heeled shoes are a popular fashion item and are worn by many women and even young girls. Numerous studies have investigated the effects of heel height, but few studies on the lateral movement of the heel axis exist. In this study we investigated and analysed the angle of inversion and eversion of the foot, adduction and abduction of the hip, joint moment inversion and eversion of the foot, joint moment adduction and abduction of the hip and grand reaction force X, in the hope to gaining a better insight into injuries that may be experienced when wearing high-heeled shoes, such as a sprained ankle. METHODS: Eleven healthy female students participated in this study. Their mean (standard deviation) age, height, and weight were 19.8 (1.2) years, 158.1 (4.5) cm, and 50.6 (4.3) kg, respectively. Prior to measurements, the purpose and procedure of this study were explained in detail, and informed written consent was obtained from all subjects. The subjects wore two pairs of shoes with a different lateral axis: lateral 30 mm, 0 mm, medial 30 mm and medial 60 mm . Before the measurements, subjects were allowed to practice walking with each pair of shoes to achieve a comfortable gait. VICON system was used to capture three-dimensional movements. The sampling frequency was 100 Hz. The system was equipped with 6 infrared cameras and 4 force plates, and there were 35 markers (plug-in gait) for each subject. VICON data were recorded while subjects walked, throughout the time of heel contact to the completion of the walking cycle. Data were recorded throughout the right stance phase of the walking cycle. We defined the stance phase of the walking cycle, ankle joint inversion, as the 'reaction phase'. The latter phase, ankle joint eversion, was defined as the 'recovery phase'. Statistical analyses were conducted using one-factor ANOVA and the Williams test. RESULTS AND DISCUSSIONS: No significance was found in relation to inversion and eversion of the foot and adduction and abduction of the hip. No significant values were found in joint moment data of inversion and eversion of the foot and adduction and abduction of the hip. One-factor ANOVA did not reveal a significant increase in grand reaction force X however a significant increase in the lateral axis (lateral 3mm versus 0 mm), (lateral 3mm versus medial 3mm), (lateral 3mm versus medial 6mm) was observed with the Williams test. Therefore, we believe that an increase in the lateral axis of heel

movement may be related to injuries that occur when wearing high-heeled shoes however further research is necessary to investigate these findings in more detail.

P2-J -68 The effect of Palm Supporter to writing for Patients with Essential Tremor

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Background and aim; Patients with essential tremor have been desired to take tool for writing letters easily due to their shivering of hand. Methods: A tool to control hand was used. The measurement of hand during writing was carried out with use of acceleration sensor. The accelerations of hand during writing lines or letters was measured and these power spectra were evaluated. Results; The tools called palm supporter showed good results that the patients wrote lines and letters easily with use of the tool. The rate to control shivering during writing was obtained to be about 90%. Conclusion: Palm supporter denoted good control for writing lines and letters. Four kinds of writing letters are used: That is, horizontal line, vertical line, circle, and Chinese letter are carried out. The method of writing is as follows: At the first time the subject writes one kind of writing letters without palm supporter and in next time the subject writes it with use of palm supporter. The writing is carried out for four kinds of letters. In order to compared with movement of hand during writing, the movement of hand without writing is measured as the rest state of hand. The data of acceleration measured is calculated by Fourier transform, and the power spectrum is evaluated. The power spectra for respective directions as X, Y, and Z are summed up in the range from 1Hz to 50Hz. The values of X, Y, and Z are evaluated as total power. The total value for three dimensions is evaluated as SQRT(XYZ) where SQRT(XYZ)=(X2+Y2+Z2)(1/2) , the unit being G2, where G is acceleration of gravity. Patients with essential tremor show various levels of shivering. In the rest state without palm supporter, SQRT(XYZ) denote 50 and 7 for the patients with the largest and the lowest shivering, respectively. The patient with largest shivering in writing horizontal line, vertical line, circle, and Chinese letter without palm supporter shows the values of SQRT(XYZ) 3523, 183, 587, and 525, respectively. On the other hand, the patient with use of palm shows the values of SQRT(XYZ) 296, 257, 114, and 470, respectively. These results denote decrease of value of SQRT(XYZ) with use of palm supporter. Especially, the decrease of SQRT(XYZ) for writing horizontal line with use of palm supporter shows from 3523 to 296, as compared with SQRT(XYZ) without palm supporter. The rate of the decrease is 91.6%; That is, the rate is calculated by (3523-296)/3523) x 100. That is, roll of palm supporter for the patient with most shivering shows to controls effectively shivering in writing horizontal line. For other patient with the lowest shivering, the

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rate of decrease is 80.1% (i.e., ((168-32)/168) ?? 100). For the letter of circle and Chinese letter, the rates of the decrease are small.

P2-J -69 The effect of Palm Supporter to writing letters for Patients with Essential Tremor

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Background and aim: Patients with essential tremor were difficult to write letters easily, so tool to control hand was desired. New tool to control shivering of hand during writing was made. Methods; The tool called as palm supporter was used during writing. The acceration of hand during writing was measured. The power spectra were calculated. Results; The effect of palm supporter was evaluated by power spectra. The decrease of shivering was evaluated to be large rate in writing letters. Especially, the effect of writing horizontal line was remarkable. Conclusion: The effect of saving shivering of hand during writing was shown with use of palm supporter.

P2-J -70 A study of tissue oxygenation in neck and forearm muscles during mobile phone tasks

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Aims: It is a worldwide trend that smartphones are used by people frequently each day and it has been associated with increased musculoskeletal symptoms both in the neck and forearm regions. Past research has mainly focused on the changes in muscle activity through studying surface electromyography in the neck and forearm muscles during computer use and mobile phone use. This study aimed to investigate the tissue oxygenation and hemodynamic changes in 2 muscles namely right upper trapezius (UT) and extensor carpi radialis (ECR) during a brief mobile phone texting task. Subjects: Twelve male young healthy subjects were recruited for the study. All of them were right-hand-dominant, and either keypad phone or touchscreen phone users without neck pain. Subjects were excluded if they had any traumatic injuries in relevant regions or suffered conditions that may affect the spine or upper limbs.Their mean age (± SD) were 20.75±0.97 yr. Average height and weight were

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175.50±3.99 cm and 61.67±6.95 kg respectively. Methods: Each subject was invited to attend 1 lab session only. It consisted of 1) a 3-min rest period (Resting T0), 2) 1st MVC maneuver, 3) a 3-min recovery period (Resting T1), 4) a 15-min texting task, 5) 2nd MVC maneuver and 6) another 3-min recovery period (Resting T2). In these 5 phases, tissue oxygenation data were measured noninvasively by near infrared spectroscopy. The ISS Imagent functional brain imaging system (ISS Inc., Illinois, USA) was used to capture tissue oxygenation data, with infrared light at a wavelength range of 670 to 850nm, and sampling frequency at 2.5Hz. A flexible probe was firmly attached to the muscle belly of the right UT while a rigid sensor was attached to the right ECR. Results: During the texting task, a significant decrease was found in oxygen saturation (SaO2) and concentration of oxyhaemoglobin [O2Hb] of UT while a significant increase in deoxyhaemoglobin concentration [HHb] was also observed. For ECR, there was no significant change in [O2Hb] while significant increase in total haemoglobin [tHb] and [HHb] were found. Comparing the three resting periods, significant increases in SaO2, [tHb] and [O2Hb] were shown while decrease in [HHb] was observed in UT. For ECR, SaO2, [tHb] and [O2Hb] were also significantly increased while a trend of decreasing [HHb] was observed although it was not significant. Comparing the two MVC maneuvers, there was no significant change in O2 desaturation rate, SaO2 lowest and 1/2 recovery time. Conclusion: The present study showed that oxygen delivery and oxygen consumption in UT and ECR muscles were affected during a 15 minutes sustained texting task on mobile phones. These results suggest that changes in tissue oxygenation may be an important factor to consider in studying the pathomechanics of musculoskeletal disorders associated with prolonged mobile phone use.

P2-J -71 Effects of one-sided loading on trunk muscle activity patterns in healthy subjects and back pain patients

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Background and Aim: Spinal compensation and stabilization during loading in everyday tasks initiated by the limbs is essential for prevention of back pain. Higher loading of the spine is evident in back pain patients. However, alterations in neuromuscular activation patterns of the trunk in different loading situations during one-handed lifting in healthy subjects (H) and back pain patients (BP) are still under debate. Therefore, the aim is to analyze neuromuscular activity patterns of the trunk in H and BP during one-handed lifting with different loads. METHDOS: After assessment of back pain via graded chronic pain scale (Korff questionnaire) all subjects (n=42) performed a short physical warm-up. Next, subjects were instructed to lift 3 times a 20kg weight (water crate) placed in front of them (two-handed lifting) onto a table of 0.75 m height. Subsequently, all subjects lifted one-handed (left-side), 3 times each, a

weight of 1kg (light), 10 kg (middle) and 20kg (heavy) in random order from the ground up on a table (0.75m height; left side of person). Trunk muscle activity was assessed with a 12-lead-EMG (6 ventral/ 6 dorsal muscles; 4000Hz). EMG-RMS [%] was averaged over the 3 repetitions and analyzed for the whole lifting cycle normalized to RMS of the two-handed lifting. Additionally, the mean (normalized) EMG-RMS of four trunk areas (right and left ventral area (VR, VL); right and left dorsal area (DR, DL)) was calculated. Data were analysed descriptively (mean¡¾SD) followed by student¢¥s t-test to comparing H and BP (¥á=0.05). RESULTS: Seven subjects (3m/4f; 32¡¾7yrs; 171¡¾7cm; 65¡¾11Kg) were assigned into BP (Korff Grade ¡Ã2) and 36 (13m/23f; 28¡¾8yrs; 174¡¾10cm; 71¡¾12Kg) into H (Korff Grade ¡Â1). H and BP did not differ significantly in anthropometrics (p>0.05). All subjects were able to lift light and middle loads. But 57% of BP and 22% of H were not able to lift the heavy load (all of them were women). EMG-RMS ranged from 33¡¾10% (DL, 1Kg) to 356¡¾148% (VR, 20kg) in H and 30¡¾9% (DL, 1Kg) to 283¡¾80% (VR, 20Kg) in BP without being statistically significant between groups regardless of weight (p>0.05). Despite, both groups showed highest EMG-RMS for VR in all lifting tasks increasing with rising load. To account for sample size differences between H and BP, a matched group analysis was applied. Results also reveal no group differences. CONCLUSION: Neuromuscular trunk compensation strategies of expected loading of different weights did not differ between BP and H. Both groups show the same specific muscular activation pattern with highest activity of the contralateral abdominal muscles (VR). Rising load leads to an increase (2- to 3-fold) of trunk muscle activity with comparable patterns between groups. Heavy loading (20kg) leads to task failure, especially in women with back pain.

P2-J -72 Estimating Expert-Based Functional Assessment Scores Using Sensor Data

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Background: EMG-based functional assessments have been used for some time to capture abnormal levels of muscle activity during the performance of predefined series of motor tasks. The work herein presented aims at developing a novel method to automatically generate estimates of expert-based functional assessment scores via analysis of the EMG data. Methods: The data recorded during a functional assessment was inspected by an expert to determine the level of EMG activity associated with muscle spasms, the amplitude of electrocardiographic (ECG) artifacts affecting the EMG signals, and the level of EMG activity at rest. The expert generated scores that captured the severity of abnormal patterns of EMG activity for muscle spasms, ECG artifacts, and EMG activity at rest. To demonstrate the feasibility of automatically generating expert-based functional assessment scores via

analysis of the EMG data, we estimated the correlation between data features derived from the EMG recordings and the scores generated by the expert. In addition, EMG data was recorded during the performance of dynamic tests and data features were correlated with expert-based scores that aimed to capture abnormalities in the magnitude and the shape of the EMG amplitude modulation. In addition, biomechanical measures including the range of motion (ROM) and the functional capacity evaluation (FCE) measure were also gathered by the expert. Associated data features were correlated with the expert-based scores. Results: The correlation between spasm scores and associated features derived from the EMG recordings ranged from 0.64 to 0.89 (mean=0.77, STD=0.11). The correlation between ECG artifact scores and data features derived to characterize them spanned the range from 0.48 to 0.79 (mean=0.71, STD=0.11). Finally, the correlation between scores aimed to characterize the activity observed at rest and associated features derived from the EMG recordings ranged from 0.66 to 0.87 (mean=0.79, STD=0.08). The correlation between data features and expert-based scores that captured the shape of the EMG amplitude modulation ranged from 0.39 to 0.69 (mean=0.55, STD=0.08). The correlation between data features and expert-based scores that captured the magnitude of the EMG amplitude modulation ranged from 0.52 and 0.78 (mean=0.65, STD=0.08). The correlation between the scores associated with the ROM and FCE and their corresponding data features ranged from 0.76 to 0.79, and from 0.90 to 0.94, respectively. Conclusions: The above-summarized correlation analyses show the data features derived from EMG and biomechanical data recorded during predefined tests that are part of the electrodiagnostic functional assessment can be used to estimate the scores generated by field experts via visual inspection.

P2-J -73 A study of neck muscle activity during mobile phone texting and association with flexion relaxation phenomenon

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Objective The purpose of this study was to examine the muscle activation in the cervical spine during mobile phone texting and the effect of muscle fatigue on the Flexion Relaxation Phenomenon (FRP) parameters. Background Static head-neck posture during prolonged mobile phone texting could lead to muscle fatigue in the cervical spine. The FRP was performed to examine the responses of active and passive components of the neuromuscular system. However, no studies investigated the change of FRP after prolonged mobile phone texting. Methods Ten healthy participants (5 males, 5 females) participated in the study. Surface electromyography was used to measure the muscle activity in the postural muscles in the cervical spine. Each participant was required to perform two sessions of 10-minute texting tasks. Neck extensor endurance test was done to induce fatigue on the

cervical erector spinae (CES) before performing the second texting task. FRP was measured before and after each texting task. Results Repeated measure ANOVA showed that cervical flexion-relaxation ratio (CFR) in left CES had significant difference across four time points ($p=0.038$). The CFR and onset angle were significantly lower after texting task 2 ($p<0.05$). Compared with after texting task 1 and 2, CFR in left CES was significantly lower ($p=0.049$) and bilateral total silence period expansions were significantly longer after texting task 2 ($p<0.05$). The muscle activation of CES during texting task 2 was significantly greater than that of texting task 1 ($p<0.05$). Conclusion Neck muscle fatigue would modulate the FRP and increase muscle activation during mobile phone texting. These results suggest that sustaining a neck flexion posture during prolonged mobile phone texting may affect the interaction between the active and passive connective structures in the cervical spine.

P2-J -74 The effect of a prolonged standing exposure on lower leg volume and muscle fatigue

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Background and aim Prolonged standing at work is associated with several musculoskeletal and venous disorders. Most mentioned disorders are low back pain, musculoskeletal lower extremity pain, chronic venous insufficiency and varicose veins. Increased muscular fatigue and lower leg volume (LLV) in subjects exposed to standing work are considered as surrogate parameters for an increased risk of the above mentioned disorders. The aim of this study was to investigate the time course of muscle fatigue and LLV during 275 min of prolonged standing exposure. Knowledge about changes in the time course would help optimize ergonomic workplace design in standing work. Methods 30 healthy subjects (15♀) spent 275 minutes (including two breaks) standing or walking in randomized order on two separate days. LLV was quantified using waterplethymography (WP) and impedance measurements at the lower leg. WP was determined before exposure and directly after 275 min of exposure. Impedance was recorded before, after 110 and 275 min of exposure time. Muscle fatigue was assessed continuously using bipolar surface electromyography at the gastrocnemius muscle with regard to an increase in electrical activity and a decrease in median frequency. Additionally, subjective ratings of discomfort were assessed by a 10-point numeric Likert-scale. Results In the standing condition LLV measured by WP increased by 109 ±63 ml after 275 min of exposure. During the walking condition changes in LLV were small (9 ±41 ml.). The difference between these two conditions was statistically significant ($p<0.0001$). Impedance decreased statistically significant after 110 and 275 min during the standing condition ($p<0.05$) but not while walking. No signs of muscle fatigue could be found in the gastrocnemius muscle by sEMG measures for both conditions. Subjective

ratings of discomfort indicated a higher amount of discomfort in the standing condition, especially at the lower back and leg region. Conclusions After 110 min of standing work the risk of venous disorders seems to be already increased. Although muscular fatigue could not be found using sEMG measures, subjective ratings of discomfort indicate increased stress to the musculoskeletal system. Finally walking seems to be a possible intervention during standing work in order to prevent from increased levels of LLV and discomfort.

DAY 3, FRIDAY JULY 8

P3-A-1 An innovative modular wireless system for the acquisition of surface EMG signals

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BACKGROUND AND AIM: The study and analysis of human movement require the acquisition of electrophysiological signals, kinematics and dynamics. Among these, surface electromyographic signal (EMG) plays a fundamental role in order to monitor muscle activity. In the last few years some systems composed of a set of wireless modules, each one allowing to acquire and transmit one bipolar EMG channel, have been developed and are now commercially available. In this work a new system is described, consisting of a set of wireless modules (sensor unit: SU) each one handling up to two EMG channels and interfacing directly to a portable device without the use of an ad hoc receiver. METHODS: The system includes up to seven SU, each one managing two EMG bipolar channels sampled at 2048 Hz with 16 bit resolution. The sampled signals are sent via a Bluetooth 4.0 link to a mobile device (notebook, tablet, or smartphone) which is configured as a Bluetooth server and acts as a receiver. The software for the acquisition and online visualization of the EMG signals has been developed using the cross-platform Qt libraries (supporting Windows, Linux, Mac,

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Android). Two different methods for the synchronization of the SUs have been developed in order to satisfy different requirements. The first one is a hardware solution for use cases requiring a good synchronization (< 1ms): the SUs are synchronized at the beginning of the measure by means of the recharge box. The second one is a software solution for use cases where synchronization is not a must: in this case synchronization is managed by the receiver device and it can be performed also when SUs are still placed on the subject. RESULTS: A prototype with 7 SUs has been realized. The noise is equal to 3.6 μVRMS RTI (Referred To Input). The performed optimization of the data packet size in order to maximize throughput allowed reaching a data rate of 666 kbps for each SU. During the transmission tests no data loss was observed in a range of 30 meters. The energy consumption of each SU is 40 mA allowing a continuous transmission of data for about twelve hours. The software has been tested with Android operating system. The time misalignment between all the seven SUs was one sample (about 500 μs) in the case of hardware synchronization and 55ms (mean) in the case of software synchronization. CONCLUSIONS: The main innovation introduced by the described system is the ability of the SUs to directly interface to a portable device acting as receiver without constraints on transmission distance or acquisition time. The hardware synchronization allows the system to be used in applications where a misalignment error below 1ms is mandatory. Such a system may be used as a tool for movement analysis and biofeedback both in clinical and telemedicine contexts. Figure. On the left the system architecture. Up to 7 sensor units (each one with 2 EMG channels) can be connected to one receiver. On the right the sensor unit is shown.

P3-A-2 Investigation of Force and EMG Measures in Competitive Swimmers

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AIM: ?Swimmers shoulder,? a term attributed to pain in and around the shoulder, is very common amongst competitive swimmers. Many university swimmers train intensively using highly repetitive motions. Overuse of the shoulder musculature is a contributing factor to shoulder pain, injury, and decreased performance in swimmers. Current research on within subject measurements, in university swimmers, during a full season is limited. The purpose of this study was to examine changes in force and muscle activation of the shoulder muscles of university female swimmers over the course of one university season (24 weeks). METHODS: Force and electromyography (EMG) were recorded from the shoulder muscles of 10 female swimmers (mean age 19±1.7 years, mean height= 165.8± 4.4cm, mean weight= 64.9± 3.8kg, right hand dominant, and performed multiple strokes in their sport). Surface electrodes were placed over the anterior and posterior deltoid and EMG data was recorded using a wireless EMG system (Noraxon USA, Telemyo 2400R 2400T). A Cybex (CSMI Inc., USA) isokinetic

dynamometer was used to measure isometric torque. Torque and EMG were sampled at a frequency of 1500Hz for 15s. Measurements were taken during four different phases of the training program: pre-season, taper, overload, and post season. Subjects were asked to produce three maximal voluntary contractions (MVCs) during horizontal arm abduction. Peak torque was measured to compare force output between trials, RMS measured muscle activity and mean frequency of the posterior deltoids was calculated to measure muscular endurance. RESULTS: No significant differences were found in strength or endurance between any of the phases of training or between pre and post-season. The only significant difference in muscular activity was in the left anterior deltoid RMS as it decreased from taper to post-season. The lack of changes in strength and endurance is evidence for the importance of dry-land strength training in elite level swimmers and that cardiorespiratory improvements are likely responsible for performance and endurance improvements after a taper.

P3-A-3 Evaluating Decomposition Methods for Electromyographic Characterization of Neuromuscular Disorders

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AIM: A framework for evaluating decomposition methods for electromyographic (EMG) characterization of neuromuscular disorders (NMDs) is proposed. Identification of motor unit potential trains (MUPTs) for characterization of NMDs can be considered an application tuned, special case of decomposition. Most important is that identified MUPTs include aspects of motor unit potential (MUP) shape and shape stability useful for disease discrimination. Moreover, the methods should be equally capable of identifying MUPTs generated by normal or diseased motor units. There is no need for complete decomposition. The focus instead is on extracting a high yield of clinically relevant information, using computationally efficient algorithms, and producing results that need no or minimal manual editing. METHODS: 1) EMG signals that reflect the neuro-dynamical, anatomical, and electrophysiological characteristics of motor units as well as the characteristics of the conducting medium and acquisition system (and their non-stationarities) are simulated. 2) A simulated motor unit firing is defined using both a firing instance and an observation range. The range identifies the duration over which the firing can be observed. A superposition is assumed to occur, when two or more observation ranges overlap. A superimposed observation range is associated with the MUPT for which the range morphology is influenced more by the MUP of this particular simulated train than by other superimposed MUPs. 3)

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Indices evaluating identified MUPT quality: a) Purity: ratio of correctly assigned MUPs to the total number of assigned MUPs; b) Splitting: the number of identified trains assigned to a simulated train and c) Merging: the ratio of the number of MUPs mistakenly assigned that belong to the second most abundant MUPT in the identified train to the number of MUPs that are correctly assigned, along with indices related to decomposition completeness d) the percentage of detected MUPTs and e) the completeness of each train using precision and recall, along with indices focused on MUPT representativeness including investigating correlations between quantitative EMG feature values calculated using simulated MUPTs and those calculated using extracted MUPTs and finally, indices evaluating computational efficiency were used. CONCLUSION: This framework quantifies issues of particular interest to the use of decomposition results for characterization of NMDs including superposition degree of influence, train representativeness, information yield and potential identification errors including misassignment, train splitting and merging. The reliance on a physiologically sound model allows not only comparison of different proposed methods for MUPT identification, but also identifies the empirical confidence limits of the obtained information. For instance, how close to a muscle fibre should an electrode detection surface be to reliably detect its electrophysiological activity.

P3-A-4 Muscle activation patterns when standing on wedges and being exposed to lateral perturbation

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INTRODUCTION: Instability of posture in the medial-lateral (ML) direction is a significant risk factor for falls in older adults. Standing on wedges changes the angular position in the ankle joints and improves postural stability seen in reduced postural sway in the ML direction. However, it is not known if standing on wedges improves body stability in the presence of external perturbations. AIM: To investigate muscle activation patterns during standing on the wedges while being exposed to lateral external perturbations. METHODS: Ten healthy young participants stood on a plane surface, on two medial wedges or two lateral wedges and were exposed to external perturbations applied to the lateral part of their right shoulder. Bilateral electromyographic (EMG) activity of dorsal and ventral trunk, thigh and shank muscles was recorded. The indexes of reciprocal (R) activation and co-contraction (C) of muscles were calculated (as the difference and sum of the integrals of EMG activity of the dorsal and ventral muscles) and analyzed during the anticipatory (APA) and compensatory (CPA) phases of postural control. RESULTS: Reciprocal activation of muscles was seen in the shank segment on the side of the perturbation while co-contraction of muscles was seen on the contralateral side. Different activation patterns were seen in the thigh and trunk segments as co-contraction of muscles on the right side and reciprocal activation on the left side. Standing

on wedges significantly affected magnitudes of C and R indexes in both shank segments, however, the activation patterns on the left and right side were similar. CONCLUSION: Standing on two wedges affects patterns of muscle activity when dealing with the lateral perturbation: reciprocal activation seen in the shank segment on the side of perturbation allows some flexibility and co-contraction of muscles on the contralateral side creates better stability needed for maintaining equilibrium.

P3-A-5 Errors in RMS amplitude estimation attributable to the Inter Electrode Distance of the surface EMG electrode grids

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BACKGROUND AND AIM: The distribution of muscle activity over the skin can be obtained by applying a grid of (MxN) electrodes. The estimated spatial amplitude (SRMS) and the image reconstructed from the recorded signals are affected by the size/shape of the electrodes, grid size, and inter-electrode distance (IED). We focus on the effect of IED on the SRMS. Large IED, i.e. low sampling in space, introduces spatial aliasing that prevents reconstruction of the true muscle activity map and results in an error in SRMS and other features. METHODS: To quantify the effect of IED on SRMS estimation, we sampled sEMG signals in space using a grid of pin electrodes (16x8; Ø=1mm, IED = 5mm, 200samp/m) and sampled in time at 2048Hz. We recorded sEMG from: a) short head of biceps brachii (BB) of a subject holding 4Kg in 90° elbow flexion, b) medial head of gastrocnemius (GS) of a subject standing on his tiptoes, and c) medial deltoid (MD) of a subject holding 4Kg in 90° abduction. Skin was rubbed with abrasive paste and rinsed with water before grid attachment. Offset removal in time, bandpass filtering, power line interference attenuation and bad channel removal were performed on sEMG of each electrode. We then Fourier transformed 30720 instantaneous maps (15s) after zero padding in space (64x64 points, 3.13 cycles/m resolution) without removing the offset of each map. To reduce the likelihood of heavy aliasing in our maps (IED=5mm), we excluded the maps in which at least one row or column showed more than 5% of its power above 87.5cycles/m. We found 56%, 61%, and 37% "alias-free" images respectively from BB, MD, and GS. These maps were saved for reconstructing high-resolution maps as reference maps (0.1mm IED) by interpolation with 2D Sinc function. Maps with larger IED were obtained by down sampling the reference maps. We computed: 1) the SRMS of each sEMG map, 2) the mean of the SRMS values over a 1s period for 15s, and 3) the RMS of each channel in 1s period and then the spatial mean over all channels. RESULTS: Larger IEDs cause an error in SRMS estimation (ErrRMS=100(RMS_IED

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- RMS_0.1) / RMS_0.1). We quantified the ErrRMS for IEDs ranging from 0.1mm to 15mm. For IED= 15mm, the ErrRMS was 17.5%, 9.0%, and 17.4% for BB, MD, and GS muscles respectively. In the different approaches to obtain SRMS (see 1), 2), 3) in the METHODS) the ErrRMS was < 3%. CONCLUSIONS: Many images sampled with IED=5mm show aliasing. The ErrRMS due to large IED (15mm) can hit 17.5% for a single map. However, if one considers epoch, an electrode grid with 15mm IED is acceptable to estimate the mean RMS value in 1s since the errors in time average out. Still, in specific applications such as differentiating signals or segmenting regions of activation in a muscle or activities of small muscles, much smaller IED is recommended (IED<5mm).

P3-A-6 The Hand Function of Stroke Patients in the View of Surface Electromyography

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Background: Movement of a healthy organism is characterized by a high degree of variability performance of a movement task. In a situation of a motor control lesion, mainly due to neurological disease, occurs in varying degrees to a fixed musculoskeletal manifestation. There are manifesting in a limiting responsiveness to changing external or internal conditions during the task oriented physical action. Objective: To determine differences in muscle activity and variability between a muscle synergy of acral and proximal muscles during reach and grip in healthy subjects and stroke patients. Methods: The experimental group consisted of 24 probands after ischemic stroke with right-sided hemi-paresis. The control group consisted of 30 healthy subjects. Muscle activity was recorded using surface electromy¬ography during the performation of selected types of grips of cylindric and spheric objects. The differences in the area under the curve record of individual muscles between the experimental and control group were statistically evaluated using the t-test for independent groups. The relationship between the activity of the muscles of the fore¬arm and shoulder girdle muscles was assessed using Spearman?s correlation coefficient for non-parametric values. Results: There were the significant differences in the size and number of statistically significant correlations distal and proximal upper extremity muscles. In stroke group was found significantly lower activity m. pectoralis major and higher activity m. trapezius. At the same time the prevailing high correlation m. pectoralis major and extensors wrist and fingers, unlike the group of healthy subjectss, when the correlation distal and proximal muscle groups appeared at random, in a lesser extent and frequency. Conclusions: The results indicate a reduction in variability of muscle activity during reaching and grasping function of stroke patients. To compensate the lack of activity of acral muscles becomes relatively fixed ?co-activation? with selected proximal muscles.

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P3-A-7 Timing and Balance: The Shoulder a Refined

SystemBackground and Aim: The shoulder is a multi-axial ball and socket synovial joint. The humeral head, owing to its limited bony constraint, translates on the glenoid fossa when the powerful shoulder girdle muscles contract. Precisely modulated muscle activity is required to maintain a stable fulcrum for arm movement. The aim of this study was to comprehensively define, using EMG, normal muscle activation and coordination throughout the globe of shoulder movement.

Methods: The study included twenty healthy participants. The activity of 8 shoulder girdle muscles (anterior, middle and posterior deltoid, upper trapezius, serratus anterior, teres major, latissimus dorsi and pectoralis major) was recorded using bipolar surface electrodes. The activity of the supraspinatus, infraspinatus and subscapularis was measured using fine wire electrodes. Participants completed 10 cycles of shoulder elevation in 4 different planes: flexion, scapular plane elevation, abduction and extension. Mean activity was compared between planes of movement using a paired ANOVA. The onset of peak amplitude was used as a measure of timing. The Pearson correlation coefficient (PCC) was calculated for pairs of muscles to investigate their coordination throughout the movement cycle.

Results: Significant differences in signal amplitude were seen across all movements for the middle posterior deltoid, with activity highest in extension (p=<0.001-0.002). Pectoralis major was significantly more active during flexion as compared to the other movements (p=<001?0.007). The upper trapezius was significant more active during extension than flexion (p=0.029). Peak activity of pectoralis major was significantly earlier in flexion as compared to the other movement planes (p=0.003-0.011). Peak activity of posterior deltoid was significantly earlier in extension (p=<0.001-0.001). Coordination between the deltoid and rotator cuff muscle groups across all movement planes was significant higher during the initial (PCC=0.79) and final (PCC=0.74) stage of shoulder elevation as compared to the mid-range (PCC=0.34) (p=0.020-0.035)(Fig. 1).

Conclusion: The study comprehensively defines normal shoulder girdle muscle activation and coordination through the globe of shoulder movement. Higher activity of the posterior deltoid during extension was expected given its line of action. Significantly higher activity was seen in the pectoralis major during flexion which was anticipated given its accepted role as a flexor of the shoulder joint. Similar findings are also reflected in the timing analysis. Muscular co-activation is essential for glenohumeral joint stability. A high correlation exists between the deltoid and rotator cuff muscle groups at the start and end range of shoulder elevation. Coordinated rotator cuff activity at these times balances the deltoid and ensures a stable fulcrum. Improved understanding of normality will facilitate a better comprehension of the changes seen in pathology.

P3-A-8 Effects of core muscle pre-activation on the recruitment of the hip muscles during therapeutic hip exercises

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BACKGROUND Therapeutic hip exercises remain as the mainstay of rehabilitation of hip conditions and injuries related to the knee and ankle based on the lower limb biomechanics. Activation of the core muscles prior to the hip muscles recruitment has been reported previously during hip exercises. However, there is a lack of the knowledge on the spatial features of hip muscles with the core pre-activation. This study examined the activity level and recruitment pattern of the prime hip muscles during various hip exercises under two experimental conditions: with and without the pre-activation of the core muscles. Methods 20 healthy females were recruited to perform 6 hip exercises (3 open kinetic chained exercises and 3 close kinetic chained exercises) under core and without core pre-activation condition. Electromyography (EMG) activities of bilateral core muscles and lumbar erector spinae and 3 prime hip muscles: gluteus maximus, gluteus medius and tensor fascia latae were acquired by surface electromyography during the hip exercises. The percentage of maximum isometric voluntary contraction (% MVIC) of the EMG activity was used to examine the effects of the core muscle pre-activation on the recruitment pattern of the prime hip muscles and back extensors. Results Effect of the core pre-activation on recruitment of the back extensors and prime hip muscles is presented in percentage change of %MVIC (in brackets) between the two experimental conditions of the core pre-activation (Figure 1). Significantly greater gluteus maximus activity was found with core pre-activation during pelvic drop exercise (59-72%), hip extension in prone lying (46%) and in 4-point kneeling (22-38%); and single leg sit-to-stand (29%). Significantly higher activities of gluteus medius

was found with core pre-activation during clam exercise (24%), hip extension in prone (16-43%) and in 4-point kneeling (31-56%) and single leg sit to stand (29%). Tensor fascia latae activity was significantly decreased during clam exercise (28%) and increased in single leg sit to stand (43%) with core pre-activation. A 19% and 12% decrease of lumbar erector spinae activities were resulted in hip extension and single leg bridging exercise respectively under core pre-activation trials. Conclusions Core pre-activation enhanced the prime hip muscles recruitment in both open and close kinetic chained exercises of the hip in extension and abduction directions. The findings suggest the potential to improve the efficacy of the therapeutic hip exercises with the core pre-activation. Significantly lower activity of the lumbar erector spinae with the core pre-activation during hip extension exercises implies less stress would be withstood by the lumbar spine when practising hip exercises. The findings demonstrated the potential use of core muscle pre-activation in promoting the efficacy of therapeutic exercises of hip and reducing stress to the lumbar spine during hip exercises.

P3-A-9 Impaired hand function is related to increased alpha band coherence between intermediate deltoid and wrist/finger flexors after stroke: preliminary findings

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Background: Loss of hand function is very common among individuals with stroke. Especially the ability to open and close the hand is often affected by abnormal involuntary wrist and finger flexion while abducting the shoulder, due to the flexion synergy. The expression of flexion synergy is believed to result from an increased dependence on corticoreticulospinal projections following the loss of corticospinal projections from the lesioned hemisphere. Such speculation is primarily supported by anatomic evidence showing that neural pathways originating from subcortical structures (e.g., brainstem) are usually characterized by divergent projections, including those shared neural drive projecting to shoulder abductor and wrist/finger flexors. Currently, evidence from functional data is still missing. EMG/EMG coherence allows for the exploration of a shared neural drive to flexor synergy muscles thus elucidating pathological neural changes underlying the loss of hand function. Prior evidence has demonstrated that EMG-EMG coherence between 8~13Hz (alpha band) is preserved among stroke individuals and may reflect the shift in the neural drive from the direct corticospinal (16~30Hz, beta band) to indirect corticoreticulospinal projections (<15Hz). Therefore, the goal of this study is to determine whether the alpha band coherence is related to impaired hand function after stroke. Methods: A total of 11 individuals (stroke: 8, control: 3) were recruited for this study. Each subject was instructed to perform maximal hand opening and hand closing while the arm lifted with a weight that equals 50% of the

maximum SABD torque. Hand pentagon area, defined as the area formed by the tips of thumb and fingers, was measured to quantify hand opening. Maximum grip force was recorded during hand closing. EMGs were collected from intermediate deltoid (mDEL), flexor carpi radialis (FCR), and flexor digitorum superficialis (FDS) at a sampling rate of 1000Hz. A DC to 450Hz low-pass filter was applied to the EMG signals. Wavelet coherence was calculated. Results: The stroke group showed significantly greater alpha band coherence than the control group during hand opening ($p<0.05$) and hand closing ($p<0.01$). To explore whether the flexors-mDEL coherence had an functional impact on the hand, a Pearson's product-moment correlation was performed across the 10 stroke participants. The shoulder abduction induced grip force was noted as synergy-induced grip force. A significant positive correlation was found between the 8-13Hz flexors-mDEL coherence and synergy-induced grip force ($r=0.5$, $p=0.034$). Among 7 out of 8 stroke subjects who were able to open the hand, significant negative correlation was found between the 8-13Hz flexors-mDEL coherence and hand pentagon area ($r=0.76$, $p=0.019$). Conclusion: After stroke, 8-13Hz EMG-EMG coherence emerges between mDEL and wrist/finger flexors and is related to the reduced ability to volitionally open and close the hand.

P3-A-10 Exploring sex differences in cervical spine muscle activity during sudden head perturbations in hockey players

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BACKGROUND AND AIM: Sex differences are apparent in the prevalence of concussions in sport. The ability of the neck muscles to dampen sudden head accelerations may be one mechanism that contributes to these differences. Our aim was to examine sex differences in head acceleration and cervical muscle activity during sudden head perturbations. METHODS: 16 competitive ice hockey players (8 female) participated. Three muscles were monitored bilaterally using surface EMG: sternocleidomastoid (SCM), scalene (SC) and splenius capitis (SPC) (Delsys, Boston, MA). Head kinematics were measured using a motion capture system (NDI, Waterloo, ON) with rigid bodies placed on the head and thorax. Cervical perturbations were induced by the release of a 1.5kg magnetized weight (dropped 15cm), attached to a wire wrapped around a height adjustable pulley secured to the participant's head. A load cell, in series with the cable determined perturbation onset. Perturbations were delivered in 4 directions (flexion, extension, right and left lateral bend) 6 times each in randomized order. EMG was sampled at 1926 Hz, low pass Butterworth filtered at 3 Hz and normalized to muscle specific maximal voluntary excitation (%MVE). Kinematics were sampled at 128 Hz and low pass Butterworth filtered at 6 Hz; angular velocity and acceleration were calculated. Three time periods were examined: baseline (-150 to -100ms pre-perturbation), anticipatory

(-15 to 0ms) and reflex (25 to 150ms post-perturbation). RESULTS: Females had significantly greater head acceleration during left lateral bend (18.6%) and flexion (23.4%) perturbations, with no difference in extension. Averaged across perturbation time periods, during flexion females had greater activity in left SPC (5.5 ± 1.8% MVE vs 3.6 ± 1.6% MVE), right SPC (3.6 ± 3.4% MVE vs 3.0 ± 2.5% MVE) and right SC (2.7 ± 1.9% MVE vs 1.6 ± 1.3% MVE), while males had greater left SCM (2.1 ± 3.1% MVE vs 1.4 ± 1.0% MVE), right SCM (1.9 ± 2.2% MVE vs 1.3 ± 0.7% MVE) and left SC (2.7 ± 3.2% MVE vs 1.9 ± 0.8% MVE). Females had greater left and right SCM and SC activity in extension, with no difference in head acceleration. There was a significant time period x sex interaction during extension, with females displaying 4.1% more overall muscle activity in the reflex period (7.2 ± 2.8% MVE vs 3.1 ± 0.9% MVE). CONCLUSIONS: There were sex differences across most variables, dependent on perturbation direction and timing knowledge, with no consistent neuromuscular strategy that could explain all directional effects. During extension perturbations, females had greater muscle activity in the reflex period, which may explain the lack of head acceleration differences between sexes. The increase in activity during reflex periods suggests a neuromuscular response to counter sudden acceleration. Further investigation of muscle onset times and co-contraction could reveal unique muscular strategies that place female athletes at a greater risk of concussions.

P3-A-11 Accurate identification of motor unit activity during dynamic tasks of the forearm muscles: perspectives for prosthetic control

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BACKGROUND AND AIM: Decomposing the surface EMG signal into its constituent motor unit action potentials allows us to investigate the behavior of motor neuron populations from muscle recordings. However, most methods assume that the performed contractions are isometric, limiting their applicability [1]. In this study we investigate whether it is possible to use EMG decomposition methods developed for isometric contractions for dynamic voluntary contractions. The target application is the control of upper limb prostheses using motor neuron activity. METHODS: EMG signals were recorded using high density surface electrode grids wrapped around the full circumference of the forearm of seven healthy subjects. Motion capture pods were used to track wrist kinematics and to provide visual feedback. The subjects were instructed to activate all degrees of freedom (DoFs) of the wrist, from the neural position to the maximal range of motion in 2.5 s three times. The recorded EMG signals were decomposed using convolutive blind source separation [1,2]. Spike trains with a sensitivity below 90% according to the pulse-to-noise ratio were disregarded [1]. The signal-to-interference ratio (SIR) was also calculated as a measure of the EMG variance

explained by the decomposed potential trains [1]. Discharge characteristics were calculated based on the instantaneous discharge rate smoothed with a 100 ms Hanning window. Means and standard deviations are reported. RESULTS: The average number of decomposed motor units per subject was 12.8 ± 5.3 for flexion, 13.5 ± 6.1 for extension, 9.8 ± 1.2 for radial deviation, 14.7 ± 5.5 for ulnar deviation, 13.5 ± 4.5 for pronation, and 9.5 ± 5.3 for supination. The SIR value was 16% ± 15%. The minimal discharge rate was 7.2 ± 3.6 pps, whereas the maximal was 19.9 ± 9.3 pps. The coefficient of variation of the inter-spike intervals was 0.35 ± 0.25. 27% of the spike trains were present in all repetitions of a given movement. CONCLUSIONS: The results showed that is possible to decompose EMG signals of voluntary dynamic contractions. Discharge rate findings are similar to those of isometric contractions except for the coefficient of variation, as expected. Although some SIR values were similar to the isometric case, the low mean indicates that in some cases not all contributing motor units were decomposed. This is consistent with our finding that only a fraction of the active motor units was detected in all repetitions. However, overall, the number of detected units is sufficient for estimating the neural drive to muscles and can therefore be used to derive robust control signals for prostheses. REFERENCES: [1] A. Holobar et al. Accurate identification of motor unit discharge patterns from high-density surface EMG and validation with a novel signal-based performance metric. J Neural Eng. 2014;11(1):16008 [2] F. Negro et al. Multi-Channel Intramuscular And Surface EMG Decomposition by Convolutive Blind Source Separation. In Press. 2016

P3-A-12 Identification of sEMG-Torque Dynamics May Reveal the Underlying Control Strategy

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Previous studies have revealed the significance of spinal feedback pathways in the neural control of limb locomotion and force generation and the manner they are modulated to satisfy the requirements of a task. We hypothesize that these feedback mechanisms cannot be as useful in fast, ballistic tasks due to the inherent spinal loop time-delays. In this work, we, for the first time, present experimental evidence on how and when the CNS may suppresses these feedbacks to accommodate the speed of the task execution. Our approach is to study this by identifying the dynamic relationship between surface EMG (sEMG) and torque in 6 healthy human ankles in isometric contractions. Subjects were provided with visual feedback of their ankle torque in real-time and instructed to voluntarily modulate it by tracking a Pseudo-Random Binary Sequence (PRBS). The peak-to-peak amplitude of the PRBS was kept small to assure the system remains in its linear range. The switching time of the PRBS was randomly selected from the set {0.1, 0.2, 0.3, 0.5, 2, 4}s. Impulse response

functions (IRF) were first estimated between the rectified sEMG and torque records using an open-loop identification technique. The IRFs had an unphysiological anticipatory component, which disappeared as the tracking speed increased. This non-causal behavior is an indicator that the data were recorded in closed-loop. We excluded vision as a potential source of feedback by repeating the experiments, removing the visual feedback. The resulting IRFs were still non-causal in slow tracking tasks. We repeated the analysis, applying a closed-loop identification algorithm that modeled the EMG-torque relation as a nonparametric IRF, and the noise as an autoregressive-moving-average process. This technique gave causal estimates confirming the closed-loop nature of this system even in the absence of visual feedback. We conclude that the control strategy is feed-forward in fast tracking tasks and switches to a feedback one in slower tasks. The cost is that the error in tracking the visual command significantly increases when the control strategy is feedforward. This technique, while useful in revealing the control strategy, cannot localize the source of the feedback. We speculate that the feedback is due to the spinal and supraspinal reflex loops with muscle proprioceptors as the main sensors.

P3-B-13 Electromyographic analysis of the scapular muscles in rehabilitation exercise: a cross-sectional study

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BACKGROUND AND AIM: The decrease in strength and the presence of imbalances in the trapezius and serratus anterior (SA) are considered causes of dysfunction of shoulder. Excessive activation of the upper trapezius (UT), combined with diminished control of lower trapezius (LT), middle trapezius (MT) and serratus anterior (SA) contributes to abnormal movement of the scapula. Moreover, has been observed an increased activation latency of scapular muscles in patients with shoulder pain. Currently, there are no reports on rehabilitation exercises based both on the scapular muscles balance and onset latency. The aim of this study was to determine the exercises that present a minor upper trapezius/middle trapezius (UT/MT), upper trapezius/lower trapezius (UT/LT), and upper trapezius/serratus anterior (UT/SA) ratio and onset latency in five common rehabilitation exercises. METHODS: A prospective cross-sectional study. Thirty young males were recruited from the University of Talca, with ages between 18 and 24, who voluntarily agreed to participant in this study. The amplitude and onset latency of UT, MT, LT and SA muscles was measured with sEMG during common shoulder rehabilitation exercises: wall-slide (WS), push-up plus (PUP), horizontal abduction with external rotation in a prone position (HAEP), external rotation in a lateral position (ERL) and low-row (LR). The exercises were classified as moderate from 100% to

80%, good from 80% to 60% and excellent <60% according to the UT/SA, UT/MT and UT/LT muscle ratios. An ANOVA with repeated measures was performed for compare each muscle latency between exercises. A Bonferroni corrected t-tests were used. A P value ≤ 0.05 was considered statistically significant. RESULTS: The exercises ERL (39.3%) and LR (53.6%) obtained and excellent UT/SA ratio. The exercises LR (52.5%), HAEP (57.1%) and ERL (59.1%) presented and excellent UT/MT ratio, while the exercise ERL (22.2%) and HAEP (36%) showed an excellent UT/LT ratio. The exercise PUP (69.3%) presented a good UT/LT ratio. The exercise WS (91.3%) showed a moderate UT/SA ratio. Repeated measure ANOVA revealed an exercise main effect for SA (F = 20.17; p < 0.0001), MT (F = 49.20; p < 0.0001), LT (F = 30.51; p < 0.0001) and UT (F = 46.82; p < 0.0001). The exercises WS and LR presented the least latency of SA (P < 0.05), while the HAEP and ERL exercises showed less latency of MT and LT (P < 0.05) (Figure 1). Finally, the PUP exercise presented the least latency of UT (P < 0.05). CONCLUSIONS: The HAEP, ERL and LR exercises were considered the most optimum to train the level and onset latency; therefore, it would be appropriate to include them in a shoulder rehabilitation program within initial phases. In change, PUP showed a higher and earlier UT activity at initial stages; therefore, it would not be appropriate to use this exercise within the first phases of shoulder rehabilitation program.

P3-B-14 8-week vibration training of the elbow flexors by force modulation

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AIM: Vibration exercise (VE) has been suggested to have beneficial effects on muscle strength, power performance, bone density, and flexibility. However, most of the previous studies focus on the effect of VE on the lower limbs by using whole body vibration platforms, while studies concerning the upper limbs focus mainly on the acute effect during or immediately after short-time VE. The aim of the present study is to evaluate the effects of VE on the elbow flexor strength after an 8-week training program by using a force-modulated VE system developed and tested as a proof of concept in a previous study. METHODS: Forty subjects underwent a biceps curl exercise twice a week for 8 weeks. Three sets were carried out in each training session, with each set reaching the maximum repetition number until failure. The subjects were randomly assigned to four groups: the vibration group (VG), the no-vibration group (NVG), the dumbbell group (DG), and the control group (CG). The NVG and the VG were trained using the force-modulated VE system. For NVG, the applied load was a ramp-up function applied to the subject's range of motion with the maximum value equal to 80% of the subject's 1 repetition maximum (1RM, Fig.1). For VG, a 30-Hz vibration (sinusoidal force) was superimposed on the rump-up load. The vibration amplitude corresponded to 60% of the baseline force. The DG was trained using dumbbells with a weight equal to 80% of the subject's 1RM, while the CG was not trained. Before and after the 8-week training period, the isometric maximum voluntary contraction (MVC) of the subject's

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dominant arm was assessed using the force-modulated VE system, while the 1 RM of the same arm was measured using dumbbells. RESULTS: After the 8-week training program, the 1RM improvement for the VG is significantly larger than that of the NVG and is comparable to that of the DG. No significant difference in the MVC improvement is found among the intervention groups (Table 1). This may be due to the nature of the adopted exercise, better suited for improving dynamic strength. CONCLUSION: Our results show force-modulated VE to produce larger 1RM improvement as compared to control. In particular, with approximated 50% work load, VE achieves 1RM improvement comparable to dumbbell exercise. This VE system seems, therefore, particular suitable for rehabilitation programs, in which heavy loads are not suitable due to impaired muscle function, weakness, and muscle mass loss of the patients.

P3-B-16 Different sagittal movements of trunk and pelvis dependent on trunk rotation direction at half-hip free sitting posture: Assessment comparable with gait analysis

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BACKGROUND AND AIM: During gait the trunk more or less rotates, flexes or extends. This kind of trunk movements could be mimicked by the trunk movements at the sitting posture with laterally half hip on the chair and other half free from support, since the free half of the hip, hemi-ischium free posture, might correspond to the free half hip at the mid stance with swinging leg not supported by the floor. The half sitting on the chair, hemi-ischium supporting posture, might be akin to the hip on the supportive leg. We here investigate effects of leftward and rightward trunk rotations on the side of hemi-ischium free posture by assessing the movements of upper center of gravity (upper COG) or sitting ground reaction pressure (COP), and applicability of this hemi-ischium free trunk rotation methods as representative of gait analysis specifically at mid stance. METHODS: Subjects were 11 healthy men (25.2±2.9 years old). The measurement was performed with two half sitting conditions, left or right half hip free from sitting with the edge of the seat placed at an intergluteal cleft. Task was the rightward trunk rotation on left side sitting position (right half free) or leftward rotation on right side sitting position. The obtained parameters were compared between left- and rightward rotations at angles of 5°, 10° and 15°. The upper COG and the inclination (°) of pelvis were measured using three-dimensional motion analysis system (ViconMX). The amount of anteroposterior movement of COP on the half sitting position side was measured using a force platforms (AMTI). Statistical analysis was made by paired t-test or Wilcoxon

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signed-rank test. RESULTS: When trunk was rotated, upper COG moved forward by the rightward rotation (e.g., 3.7 mm ahead at 15°), but relatively backward by the leftward rotation (5.3 mm back at 15°) (p<0.001). COP also moved forward by the rightward rotation (2.4 mm ahead at 15°) and backward by the leftward rotation (5.0 mm back at 15°) (p<0.01). Pelvis tilted backward significantly by the leftward rotation as compared with the rightward rotation (0.86° of the left-right difference in inclination, p<0.01). CONCLUSIONS: Because upper COG and COP moved forward and pelvis tilted forward during the rightward rotation at the hemi-ischium free posture, trunk may move to the extension direction. On the other hand, the leftward rotation induced the opposite movements to the rightward rotation. These results are well comparable for gait movements, as we consider the right leg as the functional leg possessed by 70-90% of people, and may correspond to the right leg as the leading leg for gait or the left leg as the supporting leg. The trunk rotation at hemi-ischium free posture may be beneficial for assessment of trunk movements akin to those during gait, since this assessment could be performed at a narrow space, compared with the gait analysis requiring the long distance, more than 10 m.

P3-B-17 Contribution of bilateral asymmetry in hip joint movements and trunk motion to the smooth propulsion in gait of normal adults

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BACKGROUND: Most people have a bilaterally different posture. Postural asymmetry is suggested to help the body weight shift on one limb, then allowing another limb to take a quick step to respond to the postural disturbance (Blaszczyk 2000). Gait is usually performed by the alternative movements of left and right legs with the stance and swing phases. Presumably, the postural asymmetry influences the rhythm of gait to achieve the smooth and coordinate leg movements through the kinematic coupling between trunk and lower extremities. We aim to focus motion couplings among trunk, pelvis and hip joint during the left or right single limb support phases (SLS) of gait to understand the function of bilateral difference in posture for gait performance. METHODS: Subjects with informed consents were 17 healthy men (26.6?}3.6 years old). Using 3-D motion analyzer (MX, Vicon Motion Systems) with standard markers on femurs, pelvis and trunk, movements of hip joint and trunk were measured, and relevant joint angles were assessed as the maximum, minimum and altered joint angles during SLS of left and right legs. The difference in right and left values were analyzed by paired t-test. The incidence of dominance in right or left lateral movements were analyzed by Pearson?Ls chi-squared test. The relationship among movements of hip joint, pelvis and trunk were analyzed by Pearson correlation coefficient. All analyzes were using

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SPSS with p<0.05. RESULTS: With respect to the hip joint extension during SLS, the amount of altered angle was greater in the right hip joint (13/17 persons) and in the left (4/17), indicating the greater incidence in the right hip joint usage for forward trunk movement (p<0.05, ?´2=4.73). While, the substantial maximum extension angle and altered angle of hip joint during SLS did not show the bilateral different. A correlation was obtained between the laterality of altered hip joint extension angle and the laterality of altered trunk flexion angle (r=0.64, p<0.01). CONCLUSIONS: Results suggest the right hip joint extension movements is more predominant than the left among people. Postural asymmetry was suggested that leftward laterodeviation of thoracis was common even in healthy people (Ishizuka, 2013). Presumably, the postural deviation affects the gait through the function of hip joint as follows: the right hip joint takes a role for propulsion in the stance phase, and the left hip joint takes a role for stabilization in the stance phase. The specific functional asymmetry exits in human body, as the lateral difference in hip joint and trunk movement helps their coordination due to the minimization of left or right disturbance of center of gravity. In the clinical sense, it is better to grasp the functional asymmetry in pelvis junction associated with trunk for treatments of gait disorders.

P3-B-18 Is there an age difference in voluntary activation during maximal dynamic contractions with eblow flexor muscles?

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BACKGROUND AND AIM: Skeletal muscle strength decreases with advanced age for most muscle groups [1]. This age-related reduction in maximal force is primarily due to muscle atrophy [2] but also may involve a reduced capacity to voluntarily activate the muscles [3]. Age-related reductions in voluntary activation during maximal isometric contractions were shown for some muscles but not for others [4;5], and less is known about deficits from the motor cortex during maximal dynamic contractions among old adults. The purpose of this study was to determine whether there are age differences in voluntary activation assessed with stimulation at the muscle and motor cortex during maximal isometric, concentric and eccentric contractions of the elbow flexor muscles. METHODS: Sixteen young (7 women) and 13 old (8 women) adults performed maximal voluntary contractions (MVC) with the elbow flexor muscles during isometric, concentric and eccentric contractions. Isometric contractions were performed at a 90° elbow joint angle and dynamic contractions were performed over a 60° range of motion at a velocity of 60°/s. Voluntary activation was assessed with the interpolated twitch technique using either electrical stimulation (2 trials per contraction type) or transcranial magnetic stimulation (TMS; 2 trials per contraction type), and expressed as a percentage of MVC. RESULTS: MVC torque was greater during eccentric (52.9 ± 3.6 Nm) than isometric contractions (41.2 ± 5.0 Nm; p<0.001) and both were larger than concentric contractions (30.4 ± 3.9; both, p<0.001). Voluntary activation levels were similar whether assessed at the muscle or motor cortex (1.1 ± 0.2% and 1.3 ± 0.2%, respectively; p=0.24), and similar across the three contraction types (p=0.12). Voluntary activation however, was lower for old than young adults when assessed with electrical stimulation (1.4 ± 0.3% and 0.7 ± 0.1%, respectively; p<0.01) and tended to be higher when assessed with TMS (1.6 ± 0.3% and 1.0 ± 0.1%, respectively; p=0.07). Furthermore, the variability in voluntary activation across MVC trials (standard deviation of voluntary activation) was greater for old (1.3 ± 0.1%) than young adults (0.9 ± 0.1%; p<0.001) for all contraction types. CONCLUSIONS: Old adults had lower voluntary activation of the elbow flexor muscles and were more variable across the trials compared to young adults, although the differences were small. Activation levels however, were similar across all contraction types for both young and old adults. Because activation was similar when measured with electrical stimulation and TMS, age-related limitations in neural drive may occur upstream of the motor cortex. REFERENCES: [1] Doherty, J Appl Physiol, 95:1717-727, 2003 [2] Frontera et al., J Appl Physiol, 71:644-50, 1991 [3] Stevens et al., Muscle Nerve, 27:99-101, 2003 [4] Klass et al., J Appl Physiol, 9: 31-8, 2005 [5] Hunter, J Appl Physiol, 105: 1199-209, 2008

P3-B-19 Influence of an Acute Bout of Self-Myofascial Release on the Expression of Isometric Knee Extension Force and Electromyographic and Mechanomyographic Signals of the Quadriceps Musculature

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BACKGROUND AND AIM: Self-myofascial release (SMR) techniques, such as foam rolling (FR), have demonstrated the ability to increase muscle flexibility without subsequent decrements in maximal force output. However, the potential changes in the electromechanical properties of muscle function as a result of SMR remain largely uncharacterized. Therefore, the purpose of this study was to investigate the influence of an acute bout of SMR on the expression of knee extension force and quadriceps muscle activation during a maximal isometric voluntary contraction (MVIC). METHODS: Twenty participants (10 males, 10 females; age = 24.2 yrs; height = 173.1 cm; weight = 70.7 kg) with prior FR experience completed both the experimental (EXP) and control (CON) intervention protocols on separate days (48 hours apart). Protocol order was counterbalanced across all participants. During the EXP protocol, participants completed three 60 seconds sets of FR over the vastus lateralis (VL) musculature with 60 seconds of rest between each set. During the CON protocol, participants rested for 10 minutes. For both protocols, participants completed five MVICs of knee extension pre- and post-intervention. Force output was

collected using a handheld dynamometer with the leg fixated at 60 degrees of knee flexion and was normalized to bodyweight (kg/kg). Root mean square (RMS) amplitudes of the electromyographic (EMG) and mechanomyographic (MMG) signals from the VL and rectus femoris (RF) during the greatest MVIC trial were used in all statistical analyses. Electromechanical efficiency (EME) was defined as a ratio of the MMG/EMG amplitudes. Changes in force and muscle activation were quantified as a ratio of post/pre for each variable. RESULTS: Paired t-tests (CON vs. EXP) identified no significant changes ($p > 0.05$) in force output (1.04 vs. 1.03), or EMG (1.02 vs. 0.96; 1.02 vs. 0.98), MMG (0.97 vs. 1.03; 1.07 vs. 1.06), and EME (0.97 vs. 1.15; 1.05 vs. 1.14) responses of the VL and RF, respectively. These results are consistent with previous research reporting an acute bout of SMR does not negatively influence the expression of maximal force output. However, inspection of the force data suggested that participants responded to the SMR intervention differently, with one group increasing and one group decreasing their subsequent force output. Although the post/pre force output during the EXP protocol was significantly different ($p < 0.001$) between these two groups of participants (1.13 vs. 0.90, respectively), independent t-tests identified no significant differences ($p > 0.05$) in muscle activation. CONCLUSIONS: This suggests that SMR may primarily influence the non-contractile muscle properties of some individuals, which may in turn influence their expression of maximal force output. However, it is possible that the influence of SMR on muscle function differs between a MVIC and a submaximal action. Future research should examine the influence of SMR on submaximal actions.

P3-B-20 Laterally selective stimulation of laterodorsal muscles affects the bilateral deviation in trunk alignment

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BACKGROUND: In the frontal plane of many people, the trunk deviates laterally leftwards from the vertical line across the pelvis, indicating the lateral asymmetry in the body trunk (Ishizuka et al., 2013). Patients with respiratory diseases often possess the severe asymmetry in body trunk, as the bilaterally and thoracoabdominally deformed trunk in COPD patients (Priori et al., 2013). This asymmetry or deformation of trunk might be affected by activities of muscles surrounding vertebra and ribs. We here investigate the relationship between electrically stimulated activities of laterodorsal muscles and lateral deviation of trunk position or trunk load at sitting. METHODS: Subjects were 11 healthy men (25.3±2.6 years old) at the sitting square posture, and 9 subjects were subjected further analyses since they apparently had the leftward deviation in trunk position. Electrical stimuli (maximum below sensing pain, current ~20 mA) were applied to left and right laterodorsal muscles of latissimus dorsi, lumbar quadrate, inferior posterior serratus and external abdominal oblique muscles, and their activities of contraction were confirmed by palpation. Lateral deviation of the trunk was captured using three-dimensional motion analysis system (ViconMX) with 4 markers each placed on upper thorax and pelvis. The trunk position was determined as the center place estimated from 8 marker positions. Bilateral trunk loads were measured using two compact scales placed under the hip as one scale under hemi-lateral side of the hip. Differences in obtained parameters were compared with mostly paired t-test ($p<0.05$). RESULTS: At rest, analyzed subjects had the deviated trunk position leftwards by average 4.4 mm. When electrically stimuli were applied to the left half of laterodorsal muscles, the trunk moved right wards by 5.3 mm from the rest position($p<0.05$). When stimulated the right laterodorsal muscles, inversely trunk moved leftwards by 2.3 mm ($p<0.05$). Accordingly, the left-right ratio of trunk load altered to be increased toward the direction opposite to the stimulated side ($p<0.01$) CONCLUSIONS: Results apparently indicates that the activation of bilaterally one side of laterodorsal muscles induces the trunk movement towards the other side of stimulated muscles of healthy men. The normal deviation of trunk may be attributed by the bilateral difference in trunk muscles. In contrast, when much deviated like pulmonary obstructed patients, the activation of opposite trunk muscles of laterodorsal muscles may help the severe deviation normalize toward upright of the trunk position. Thus, the laterally selective stimulation of trunk muscles may be a feasible strategy for rehabilitation in trunk-related disorders.

P3-B-21 Spatial EMG signal properties in human biceps femoris muscle during running on the treadmill

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BACKGROUND AND AIM: It is very important to elucidate the mechanism of muscle injury such as a pulled muscle. The aim of this study is to elucidate the difference of spatial muscular activity by surface EMG signal during the running on the treadmill. METHODS: The subjects were 5 healthy male volunteers averaged age 22.4 years and they did not have muscle injury. The subject ran on the treadmill at 6km/h, 9km/h, 12km/h and 15km/h. The surface EMG signals were recorded from the biceps femoris muscle. The wireless EMG sensor with inter-electrode distance of 20 mm (IP 3PAD, Oisaka Electronic Equipment Ltd.) was placed in three location of the proximal, distal and middle point on the muscle. The frequency range and the gain of EMG amplifier were set from 19.6 Hz to 442 Hz and 60 dB, respectively. In order to analyze the running cycle, the 3 axis accelerometer and joint angle meter were installed on the knee joint. All recorded signals were stored on a personal computer through an A/D converter with a 16-bit resolution and with a sampling frequency of 1,000 Hz. The EMG activity (RMS) of each electrode location was normalized by the highest EMG activity (100%RMS) during an isometric maximum voluntary contraction. RESULTS: The %RMS increased on the last half of swing phase in all running speed. At the running speed over 9km/h, the %RMS increased on the first half of stance phase. The spatial difference and crosswise difference of %RMS was not recognized in four subjects. But in one subject, the %RMS of proximal point on right foot was significantly increased on the first half of stance phase at 9km/h, 12 km/h and 15 km/h. CONCLUSIONS: The relationship between the exercise intensity and the mechanism of muscle injury such as a pulled muscle might be clarified by the spatial muscular activity by surface EMG.

P3-B-22 Relationship between dynamic postural control ability with voluntary sway and passive sway and lower limb muscle activity

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BACKGROUND AND AIM:Fracture or fall accounts for 10% of the cause of the care in Japan.Dynamic postural control ability is necessary for fall prevention in our daily lives.Dynamic postural control ability is categorized voluntary sway and passive sway. Decline of dynamic postural control ability as well as decrease the muscle amount of the lower limb with aging.In this study, we consider the relationship between dynamic postural control ability and lower limb muscle activity by comparison of the young and older adults. METHODS:We performed two tests in measurement of dynamic postural control ability. 1. voluntary sway on the stabilometer 2. passive sway on the unstable tiltboard In addition, we measure lower limb muscle activity of Vastus lateralis（VL）, Biceps femoris（BF）,Tibialis anterior（TA）and Gastrocnemius（GAS）. RESULTS:The results showed that older adults declined dynamic postural control ability and increased lower limb muscle activity more young.In particular, there was increased lower limb muscle activity of the antagonist by voluntary sway, and there was increased lower limb muscle activity of the femoral region by passive sway. CONCLUSIONS:Older adults increased lower limb muscle activity by co-contraction, and it was suggested that they stabilized dynamic postural control ability using hip strategy.

P3-B-24 Running related gluteus medius muscle function in health and injury: A systematic review with meta-analysis

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BACKGROUND AND AIM: Despite the benefits of running for a number of body systems, musculoskeletal injuries in runners are common. The inability to control pelvic equilibrium in the coronal plane is thought to contribute to running related injuries. This lack of pelvic control in the frontal plane can stem from dysfunction of the gluteus medius. The aim of this systematic review was therefore to: (i) compile evidence of the activity profile of gluteus medius when running; (ii) identify how gluteus medius activity (electromyography, EMG) varies with speed, cadence and gender when running; (iii) compare gluteus medius activity in injured runners to matched controls. This information may assist with the development of targeted rehabilitation strategies. METHODS: Seven electronic databases were searched for terms under three main concepts; gluteals, running and EMG. The title and abstracts of studies were screened independently by two authors according to a pre-determined eligibility criteria. Studies were eligible if they recorded gluteus medius muscle activity with EMG in healthy runners; or compared healthy runners to an injured sample. Effect sizes and 95% confidence intervals were calculated from included studies to determine the effect of running speed, running step rate, gender and injury on gluteus medius activity. Data were pooled in a meta-analysis where two or more comparative studies (e.g. injury vs control) were available. The quality of the body of evidence for each meta-analysis was rated according to the GRADE criteria of the Cochrane collaboration. RESULTS: 13 studies were included in this review; mean participant age 21 to 39 years; running experience varied from recreational runners to varsity track athletes. The burst activity profile across a running stride was illustrated in four studies. Gluteus medius activity was monophasic, with peak activity occurring in the initial loading phase of running. Gluteus medius amplitude and duration increased with running speed, although the response was greater in females (4 studies). There was greater EMG amplitude in late swing when running at a higher cadence (1 study). Five studies assessed the impact of injury (Achilles tendinopathy; patellofemoral pain syndrome (PFPS)) on gluteus medius running activity. The most consistent finding across both injuries was a reduction in gluteus medius EMG duration in injured runners compared with controls. Results could be pooled for PFPS (Fig 1), with moderate quality evidence from two studies indicating a moderate and significant reduction in duration of activity (ES=-0.52[-0.97, -0.08]). CONCLUSION: Gluteus medius is most active in the initial phase of stance, however, duration of activity appears to be the outcome that is impaired in injured runners. Strategies such as increasing running step rate (cadence) can potentially facilitate gluteus medius recruitment and may prove beneficial to runners with suspected dysfunction of coronal plane control.

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P3-B-25 Biomechanical Strategies of Drop Jump Depending on Human Knee Extensor Eccentric Strength

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BACKGROUND AND AIM: The eccentric contraction during the landing or breaking phase of a drop jump plays an important role. Although it has been known from frog muscle experiments by Hill (1938) that eccentric force increases beyond the maximum isometric force up to the some point, that's generally not the case for in vivo human muscles during voluntary contractions, typically for untrained people. In recently studies, untrained humans may be unable to activate their eccentric muscles optimally (Enoka, 1997; Sale, 1988). The purpose of the present study was to investigate how the eccentric strength of human knee extensor muscles influenced the biomechanical strategies of drop jump performance. METHODS: Based on the eccentric knee extension torque, sixteen subjects were categorized into the low eccentric (LowECC; n = 10) and high eccentric (HighECC; n = 6) strength group. Lower limb kinematics and kinetics during the drop jump performance were analyzed using a 3D motion capture system (VICON, Oxford Metric LTd. US) with a force plate (AMTI OR6-7, Watertown, MA). In addition, fascicle behavior of the vastus lateralis (VL) was assessed using an ultrasonography (LogicScan 128 EXT-12 kit, Lithuania) and muscle activation was monitored using a surface EMG system (8 channel DELSYS, Boston, MA). Joint stiffness was calculated as the ratio of peak joint moment to joint angular displacement at the braking phase. RESULTS: During the drop jumping, HighECC group showed short contact time compared to LowECC group. In absolute jump height, no significantly different was observed, but the jump height normalized to their height showed that the HighECC group jumped higher compared to LowECC group. HighECC group showed less peak flexion angle in the lower extremities during drop landing and they created higher ankle and knee joint power during both braking and propulsion phase than LowECC group. The knee and ankle joint stiffness were shown that HighECC group significantly was greater than LowECC group. Fascicle length change of the VL during the braking phase was significantly higher in LowECC groups than HighECC group but, during propulsion phase no significantly different between two groups. CONCLUSIONS: To see whether knee extensor eccentric strength capacity might be a crucial factor for the landing strategy, this study examined whether landing dynamics from drop jumps differed among HighECC and LowECC groups. It has been observed that the HighECC group, comparing with the LowECC group, used stiffer landing strategy for a drop jump, indicating that higher eccentric strength might enhance the breaking capacity during braking phase and result in higher energy return during the following propulsive phase. In conclusion, the results of this study concluded that drop jumping strategies could be adjusted based on subject's eccentric strength capacity.

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P3-B-26 Effect of bilateral fatigue in the knee extensor muscles on crank power during sprint cycling

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BACKGROUND AND AIM: The ability to produce maximal crank power during sprint cycling is influenced by the force-generating capacity and activation level of the lower-limb muscles. It is often assumed that a reduction in the force-generating capacity of the knee extensor muscles is largely responsible for decreases in crank power during maximal cycling [1], even if the direct contribution of the work produced by the knee extensors to crank power is limited [2]. The aim of this study was to investigate the effect of repeated maximal bilateral knee extensions on crank power and activation level of the lower-limb muscles during sprint cycling. METHODS: 10 subjects performed a maximal 30-s cycling sprint immediately after 120 maximal bilateral knee extensions and in a control condition. Maximal voluntary force (MVF), twitch force (Qtw) and voluntary activation (VA) of the knee extensors were measured prior to maximal knee extensions as well as prior to and after the cycling sprints. Average crank power, cadence and EMG amplitude for vastus lateralis (VL), rectus femoris (RF), biceps femoris (HAM), gastrocnemius (GAS) and gluteus maximus (GMAX) were calculated during the 30-s cycling sprints. Mean ± SD values are reported. RESULTS: MVF (218 ± 109 N vs. 507 ± 193 N), Qtw (77 ± 26 N vs. 137 ± 41 N) and VA (59 ± 19% vs. 90 ± 6%) were all lower following maximal knee extensions compared to control ($P < 0.05$). Crank power (541 ± 132 W vs. 654 ± 160 W), cadence (88 ± 5 rpm vs. 95 ± 4 rpm), knee extensor EMG (RF: -16 ± 12%, VL: -9 ± 10%) and EMG of HAM (-21 ± 8%), GMAX (-14 ± 13%) and GAS (-12 ± 13%) were lower during the cycling sprint performed after maximal knee extensions compared to the control sprint ($P < 0.05$). MVF (283 ± 86 N vs. 460 ± 157 N), Qtw (60 ± 20 N vs. 89 ± 27 N) and VA (75 ± 11% vs. 94 ± 3%) remained lower after the sprint performed following maximal knee extensions compared to the control sprint ($P < 0.05$). CONCLUSION: Completion of maximal bilateral knee extensions resulted in substantial levels of peripheral and central fatigue in the knee extensor muscles which decreased crank power during the subsequent sprint. However, reductions in the activity levels of GMAX, HAM and GAS during the sprint are also likely to have contributed to decreased crank power. Therefore, large reductions in the force-generating capacity of the knee extensor muscles (-52 ± 22%) may have a relatively small contribution to decreases in crank power (-17 ± 8%) during sprint cycling. REFERENCES: [1] Fernandez del Olmo, et al.,Scand J Med Sci Sports, 2013. 23(1): p. 57-65; [2] Zajac, et al.,Gait Posture, 2002. 16(3): p. 215-32.

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P3-B-28 Changes in postural control and dual task performance following an ultramarathon

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BACKGROUND AND AIM: Postural control following endurance events has not been well studied. The aim was to investigate the effect of a single bout of prolonged aerobic exercise on traditional measures of postural control and dual task performance following a 27-km or 50-km trail race. METHODS: Twelve 50-km and two 27-km runners (age = 40.1 (11.8) years, race time = 6.5 (1.9) hours) completed postural and dual task measures on a VSR sport forceplate (Natus Medical Inc) the day before and immediately following the race. Postural conditions included standing eyes open or closed, on either the flat plate or foam, for 40 seconds. Dual task performance involved completing a two-choice reaction time test while standing on the flat plate or foam for 80 seconds. Postural variables included anterior-posterior (AP) and mediolateral (ML) path length, velocity, root mean square (RMS) and median frequency based upon center of pressure (COP). Statistical analysis was performed using a 3 factor ANOVA with repeated measures (pre-post, eyes open-closed, flat-foam surface). Dual task analysis was also conducted with a 3 factor ANOVA with repeated measures (pre-post, dual-non dual task, flat-foam surface). RESULTS: Significant ($p<.05$) differences in postural control were observed before versus after the ultramarathon. AP path length ($p=0.017$), AP velocity ($p=0.017$), and AP RMS ($p=0.022$) all increased after running. ML RMS ($p=0.010$) and ML median frequency ($p=0.004$) both reduced after running. Dual task analysis showed a pre-post by task interaction for ML RMS ($p=0.026$) demonstrating that performing a two-choice reaction task increased ML RMS compared to a reduction in RMS under non-dual task conditions. Reaction times were not significantly altered between pre-post or surface conditions. CONCLUSIONS: These data demonstrate that following an endurance run, postural sway in the AP direction is magnified. Additionally, ML sway reduced in both frequency and magnitude following the run, but a two choice reaction task produced an opposing impact on the control of ML RMS. Further studies are required to determine the duration of the effect.

P3-B-29 Kinematics Comparison between Dominant and Non-Dominant Lower Limbs in Thai Boxing

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Title: Kinematics Comparison between Dominant and Non-Dominant Lower Limbs in Thai Boxing Abstract: BACKGROUND AND AIM: Muay Thai, also known as Thai Boxing, is

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Thailand's national sport, and it involves athletes using different stand-up striking and clinching techniques. There are a limited number of research studies that have examined Thai Boxing skills and specifically none have examined the kinematics of the dominant and non-dominant legs while in a double collar or double underhook clinching position. The purpose of the study was to investigate the kinematics of the dominant (right) and non-dominant leg (left) between the double collar and double underhook Thai Boxing clinching positions. METHODS: Participants executed six continuous knee strikes with the dominant leg and non-dominant leg in each of the two clinching positions for twelve knee strikes. A standard two-dimensional video motion analysis was conducted. RESULTS: The results revealed statistical significant difference at the hip joint angle between both clinching positions (p = .013) but not at the knee and ankle joints. There were no statistical significant differences in the joint angular velocity and acceleration for the hip, knee, and ankle joint between both clinching positions. However, there was a statistical significant difference found in the joint angular velocity for the knee joint (p = 0.00) between the dominant and non- dominant leg. Lastly, there was a significant correlation of the joint angle (r = 0.65 and 0.63; double collar and double underhook) and the angular velocity (r = 0.76 and 0.67; double collar and double underhook) for the left and right knee between both clinching positions. In addition, there was a significant correlation of the joint angle between the left and right hip (r = 0.66) for the double collar position but not for the double underhook position. CONCLUSION: This study demonstrates the importance of hip joint flexibility and the angular velocity of the knee between the dominant and non-dominant leg. Future research studies investigating the impact of the knee at the point of contact in the Thai Boxing clinch positions among group of elite mixed martial arts athletes are warranted.

P3-B-30 Forearm muscle function investigated by EMG in tennis players suffering from tennis elbow

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BACKGROUND There is no consensus about the main aetiology of Lateral Epicondylitis (LE) or Tennis Elbow. While electromyographic assessment of alterations in neuromuscular control and activation patterns of forearm muscles has received increasing interest as potential intrinsic factors in non-tennis players, there has been insufficient attention in tennis players. The purpose of present review was to search the literature for the electromyographic studies of forearm muscles in tennis players in order to (1) identify related implications for LE, (2) highlight key technical and methodological shortcomings, and (3) suggest potential

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pathways for future research. METHODS An electronic search of PubMed, Scopus, Web of Science, and Google Scholars (1980 to October 2014) was conducted. Titles, abstracts, and full-text articles were screened to identify "peer-reviewed" studies specifically looking into "electromyographic assessment of forearm muscles" in "tennis players". RESULTS After screening 104 articles, 13 original articles were considered in the main review involving a total of 216 participants (78% male, 22% female). There were indications of increased wrist extensor activity in all tennis strokes and less experienced single-handed players, however with insufficient evidence to support their relationship with the development of LE. Studies varied widely in study population, sample size, gender, level of tennis skills, electrode type, forearm muscles studied, EMG recording protocol, EMG normalisation method, and reported parameters. As a result, it was not possible to present combined results of existing studies and draw concrete conclusions in terms of clinical implications of findings. CONCLUSION There is a need for establishment of specific guidelines and recommendations for EMG assessment of forearm musculature particularly in terms of electrode and muscle selection. Further studies of both healthy controls and tennis players suffering from LE with adequate sample sizes and well-defined demographics are warranted.

P3-B-31 Neuromuscular efficiency of trunk muscles is decreased during an acute pain episode in low back pain patients

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AIM: Accepted pain models suggest a centrally controlled strategy of trunk stiffening in LBP, however, supporting evidence is limited mainly to isometric measurements. Based on indications of an impaired neuromuscular efficiency (NME, amount of muscular activation needed to generate force) in LBP, a dynamic protocol comparing relative trunk muscle activity during submaximal voluntary contractions (SMVC) may be a promising alternative. This study investigated the influence of acute LBP on neuromuscular efficiency and activation pattern of trunk muscles during dynamic trunk extensions. METHODS: Eight LBP patients (3 males: 38±16 yrs, 89±8 kg, 1.90±0.11 m; 5 females: 44±12 yrs, 57±12 kg, 1.62±0.06 m) were measured in test-retest design (38±30 d in between) during acute pain (AP, pain level 36±17/100 VAS, Korff>1) and after remission of pain (NP, 7±6/100 VAS, Korff<1) (mean±SD). Participants were equipped with a 12-lead bilateral SEMG (myon m320, myon AG, Switzerland) on trunk extensors (M. erector spinae L3/Th9 (ESL/EST), M. latissimus dorsi (LD)) and flexors (M. rectus abdominis, Mm. obliquus externus/internus). The protocol consisted of isokinetic concentric trunk strength tests (Con-Trex MJ, TP 1000 module, Physiomed AG, Germany) in standing position (ROM: 45° flexion to 10° extension, velocity: 45°/s): warm-up, 5 MVC, each 5 SMVC with bio feedback at 20, 40, 60 and 80% MVC peak torque [Nm], and another 5 MVC for fatigue control. EMG amplitudes (isokinetic phase, RMS [V]) of extensors

during rest and SMVC trials were normalized to MVC activity [%]. Then, all back muscles averaged (ALLext) were compared by paired t-test (AP, NP) and two-way repeated measures 2 (AP, NP) x 5 (rest, SMVC20-80) ANOVA for an effect of pain status over SMVC loads (α=.05). Similarly, co-activation of abdominal muscles (ALLflx, % agonistic peak activity) and of synergistic back muscles (% overall trunk extension activity) was analysed. RESULTS: Peak torque of MVC was 200±66 Nm (AP) and 211±58 (NP). Normalized EMG values of ALLext showed on average 10±6% higher activity values during AP compared to NP, resulting in a statistical significant difference at SMVC80 (17±12%, p<.01) and an aggregated pain*load interaction effect of F(1,4)=4.377, p<.01. Co-activation of ALLflx was always higher during AP (23±11%) compared to NP, however, differences stayed below level of significance. Individual synergistic contribution was higher for EST (p<.05 at rest and SMVC40-80), lower for ESL (p<.05 at SMVC80) and at lower intensities for LD (p<.05 at rest and SMVC20), resulting in a statistical significant pain*load interaction effect for LD only (F(1,5)=4.415, p<.05). CONCLUSION: NME of trunk extensors has been found to be decreased during acute LBP. This was accompanied by hyperactivity of extensors and flexors, and a redistribution of synergistic extensors towards increased thoracic activity. The results support LBP intervention strategies focusing on neuromuscular trunk control.

P3-B-32 Drop jump kinematic curves differ for ACL-deficient and ACL-reconstructed individuals ~20 years post-injury compared to controls

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Purpose: Unilateral anterior cruciate ligament (ACL) ruptures can influence not only one-legged tasks, but also two-legged dynamic movements decades after rehabilitation. Our aim was to examine and compare drop-jump kinematic curves between and within ACL-reconstructed, ACL-deficient, and non-injured controls. Methods: Subjects with ACL ruptures treated on average 23 (16-29) years ago conservatively with physiotherapy only (ACLPT, n = 26) or in combination with reconstructive surgery (ACLR, n=28) and age- and sex matched controls (n=25) performed a drop jump from a height of 40 cm. 3D knee-, hip-, and trunk-kinematics and jump height were captured (8 Oqus cameras, 240 Hz, Qualisys AB) and the time from the box landing to the lowest position of the pelvis upon landing from the rebound jump was analyzed with a 6 degrees of freedom model. Knee separation curves were also calculated as the distance between the two knee-joint centers divided by the distance between the two hip-joint centers to reflect a measure of the dynamic valgus. Kinematic curves were subsequently compared using functional data analysis (ANOVA) methods within-groups (i.e., comparing between legs) and between-groups (i.e., comparing

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the injured [and non-injured] legs of ACL subjects to the non-dominant [and dominant] legs of controls). Level of statistical significance was set to $p < 0.05$. Results: The ACL-treated groups landed from the box with lesser knee and hip flexion in both legs than controls. In addition, ACL groups had greater external rotation at the knee for their injured leg compared to the non-dominant leg of controls during the initial phases of both landings. The ACL groups also exhibited greater dynamic valgus during the flight phase and while landing from the rebound jump. Furthermore, ACLR landed from the box with lesser trunk flexion than controls. Between-leg differences were not detected, except for in ACLR where the injured leg exhibited greater hip internal rotation than the non-injured leg during most of the drop jump. Compared to controls, the deviations in movement curves were more pronounced in ACLPT at the knee, while they were more evident in ACLR at the hip. Controls (37 cm) had a higher mean jump height than ACLPT (31 cm), but not when compared to ACLR (34 cm). Conclusions: Specific functional deviations from controls during the drop-jump task were detected ~20 years post-ACL rupture independent of treatment, while no marked differences were observed between ACLR and ACLPT. However, the different patterns exhibited in hip and knee kinematics compared to controls for ACLR and ACLPT possibly reflected distinct compensatory mechanisms in these two groups. Analyzing the entire drop-jump kinematic curves, rather than just when landing from the box, provided additional insight into potential coping mechanisms and compensatory strategies that might have otherwise been missed using traditional statistical approaches.

P3-C-33 Modulations of correlated neural oscillations for improving muscle coactivation control due to repetition and practice

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BACKGROUND AND AIM: Voluntary muscle contraction often involves correlated neural oscillations including "common drive" (<5 Hz). The purpose of this study was to clarify the modulations of correlated neural oscillations that may accompany the improvement of coactivation control of antagonist muscles due to a repetition or a bout of practice. METHODS: Sixty healthy young adults (22.5 ± 3.0 years old) were divided into 3 groups: Co-activation, Contraction, and Control. All participants completed a target-reaching test before and after a bout of practice using the amplitude of surface EMG (AEMG) of biceps brachii (BB) and triceps brachii (TB). EMG was also collected from brachioradialis (BR). In the test, target was divided into a varying-level coactivation, followed by a constant-level coactivation. BB and TB had opposite target levels (4% and 12% of maximum AEMG). During the practice period, Coactivation group practiced repetitive varying-level activation for both muscles at a time; Contraction group practiced with agonist contractions at a time; Control group rested without voluntary contractions. RESULTS: In varying-level coactivation comparing before and after the practice period, mean squared error of AEMG decreased by 21% ($P < 0.01$) and latency of reaching target decreased by 230 ms (by 17%, $P < 0.01$) across groups, with no significant change for variability. Negative peak in cross-correlation function (CCF) was observed in rectified EMG at low frequency (0.5-5 Hz) between the antagonist pairs in varying-level coactivation with opposing orientation. After the practice period, the negative peak became more negative by ~47% ($P < 0.\ 01$) for both BB-TB and BR-TB pairs. In constant-level coactivation, mean squared error and variance of AEMG decreased by 20% ($P < 0.01$) and 17% ($P < 0.01$), respectively, across groups after the practice period. Positive peak in CCF (rectified EMG, 0.5-5 Hz) was observed between the involved muscle pairs, and it decreased by 18% ($P < 0.01$) for BB-BR pair, 19% ($P < 0.01$) for BR-TR pair, and 10% ($P = 0.067$) for BR-TR pair after the practice period. Improvements of AEMG adjustment specifically in Coactivation group were evident only for varying-level coactivation, but they did not accompany a unique change in CCF between EMGs. CONCLUSION: All three groups improved coactivation control of antagonist muscles just due to a repetition. Presence and associated increase in the negative coupling between antagonist muscles suggests the potential involvement of low-frequency reciprocal coupling for reaching opposing targets faster and more accurately. Associated reduction in the positive coupling across muscles during constant-level coactivation suggests the reduced common drive for maintaining distinct activation levels between muscles. Modulations of these intermuscular coupling are achieved by a simple repetition and not to be further enhanced with a bout of Coactivation practice. Supported by NSF IIS 1317718

P3-C-34 Neural control of human precision and power grips

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Current evidence supports the view that distinct descending motor pathways contribute to the control of hand motoneurons during different grip configurations. For example, studies in non-human primates demonstrated that cortico-motoneuronal cells preferentially discharge during fine precision grip but to a much lesser extent during a power grip. Here, we examined the contribution of the corticospinal pathway, and cortical and subcortical mechanisms to the control of precision and power grip in intact humans. Using motor cortical and cervicomedullary stimulation, we measured motor evoked potentials (MEPs), cervicomedullary MEPs (CMEPs), and the activity in intracortical circuits (suppression of voluntary electromyography, svEMG) in the first dorsal interosseous (FDI) muscle during

index finger abduction (control task), precision grip of a small cylinder between the index finger and thumb, and power grip at matched levels of background EMG activity in the FDI muscle. We found that MEP size decreased during precision (by 26.5 ± 19.9%) and power (by 48.1 ± 19.3%) grip compared with index finger abduction. MEP suppression was larger during power compared to precision grip ($p < 0.001$). Notably, MEP latency was delayed during power grip (by 0.6 ± 0.4 ms) compared to the other tasks. CMEPs were suppressed during precision (by 33.4 ± 21.7%) and power (by 36.4 ± 16.6%) grip to a similar extent compared to index finger abduction. Whereas the svEMG decreased to a larger extent during power (by 49.1 ± 18.0%) than precision (by 28.1 ± 23.7%) grip compared with index finger abduction and these changes correlated with changes in MEP size. Altogether our results support the view that different descending motor pathways contribute to the control of precision and power grip in intact humans.

P3-C-35 Test-retest reliability of a novel supine knee joint position sense test.

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BACKGROUND AND AIM: Knee joint proprioception is believed to be a key factor regarding knee injury prevention and knee function outcome following rehabilitation from, e.g. anterior cruciate ligament (ACL) injury. Joint position sense (JPS), the ability to reproduce a joint angle, is a common way to assess proprioception ability. However, no gold standard to validly and reliably assess knee JPS exists. Our aim was to investigate the test-retest reliability of a new supine knee active-active JPS test. METHODS: Fifteen physically-active young adults (18-27 yrs) have so far been tested on two occasions (7-30 days between). Participants lay supine with legs at approximately 100° knee flexion and feet strapped to a custom-built manual leg extension/flexion device. Using the dominant leg, three full active leg extension/flexion practice trials were performed at an attempted knee angular velocity of 10°/s during extension with real-time feedback. This angular velocity was attempted for all test trials during extension but without visual feedback. Participants then performed ten test trials by extending the leg until receiving a visual stop cue at a knee flexion angle unknown to them (40° or 65° knee flexion). Once static they pressed a hand-held trigger to confirm the knee target angle (TA). After two seconds they flexed the leg back to the start position then extended the leg to the believed TA, stopped and pressed the trigger. This position was denoted the knee reproduction angle (RA). The protocol was repeated with the non-dominant leg. An eight-camera motion capture system (Oqus, Qualisys, 240 Hz) calculated knee angles from six retro-reflective markers. Absolute error (AE), the difference between the TA and RA of a trial, was calculated for all trials. The mean AE of the five trials for both angle conditions for each leg was used for analysis. Relative reliability and absolute reliability were

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assessed using intraclass correlation coefficients (ICC) and standard error of measurement (SEM), respectively. Analysis of variable error (VE) and constant error (CE) are underway. RESULTS: Results suggest high reliability for the 65° knee angle condition using the non-dominant leg (ICC = 0.72, SEM = 0.72°). Moderate reliability was seen for 40° (ICC = 0.58, SEM = 0.70°) and 65° (ICC = 0.55, SEM = 0.90°) using the dominant leg. Lower reliability was seen for 40° using the non-dominant leg (ICC = 0.38, SEM = 1.31°). CONCLUSIONS: Preliminary results suggest low to high reliability for this supine knee JPS test. Ongoing data collection will increase the current sample size and further analyses will include variable and constant error and the ability of participants to maintain the desired knee extension angular velocity and its effect on error. If showing sufficient reliability, the test should be validated by also being tested on individuals believed to have knee proprioception deficits, i.e. ACL-injured persons, and be compared to existing knee JPS tests.

P3-C-36 Does the motor cortex contribute to electrically-evoked contractions in humans?

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BACKGROUND AND AIM: Neuromuscular electrical stimulation (NMES) generates contractions by depolarising motor axons beneath the stimulating electrodes. Thus, the signals that produce these contractions traverse a purely "peripheral" pathway. However, we have shown that "central pathways" can also contribute to contractions produced by NMES, when the depolarisation of sensory axons recruits motor neurons via spinal reflex pathways. Presently, we investigate whether the central pathways that contribute to contractions produced by NMES involve "long-loop" transmission through the motor cortex. One way to assess this cortical contribution is by using subthreshold transcranial magnetic stimulation (sTMS), whereby TMS intensity is set below motor threshold (MT). sTMS has been shown to suppress electromyographic activity (EMG) during voluntary contractions (VOL) by reducing the output of the motor cortex. In this way, suppression of EMG by sTMS indicates a cortical contribution to muscle contractions. The purpose the present study was to examine if the motor cortex contributes to contractions elicited by NMES and, if so, to compare the relative amounts of cortical contribution during NMES and VOL. We hypothesized that suppression of EMG by sTMS would be present during both NMES and VOL, however, we expected that a greater amount of suppression would occur during VOL. METHODS: EMG was recorded from the right tibialis anterior (TA) muscle in four healthy volunteers with no known neurological impairment. 100 pulses of sTMS (figure-eight coil; ~73% MT) were delivered over the left motor cortex while subjects received five 60 s trains of NMES (100 Hz, 1 ms pulse duration) over the right common peroneal nerve or while subjects held a VOL contraction of similar

amplitude. NMES and VOL were matched by the level of background EMG in the TA. EMG suppression was considered to be statistically significant when the level of EMG fell below two standard deviations of the mean background EMG. The magnitude of this suppression was quantified as the duration (ms) and amplitude (mV) of EMG below the level of the two standard deviations. RESULTS: A significant suppression of the EMG was present in two subjects during NMES, and in three subjects during VOL. In the two subjects exhibiting suppression during NMES, the amplitude and duration of suppression were 0.02 ± 0.02 mV and 15.10 ± 11.17 ms, respectively. In the three subjects exhibiting suppression during VOL, the the mean amplitude and duration of suppression were 0.14 ± 0.06 mV and 21.73 ± 6.64 ms, respectively. CONCLUSION: These data suggest that transmission along pathways traversing the motor cortex contribute to NMES contractions in some participants. However, these data also suggest a greater cortical contribution occurs during VOL versus contractions of equal amplitude produced by NMES. It is likely that spinal pathways also contribute to NMES contractions, resulting in a lesser reliance on cortical output.

P3-C-37 Is human walking behavior better predicted by energetics or stability: a case-study involving human-structure interactions

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BACKGROUND AND AIM: Large lateral oscillations of bridges and walkways due to pedestrian synchronization have been observed in many cases, the most famous example of such an event occurred on the opening day of the London Millennium Bridge. Data from such events could provide useful ways to test control strategies for bipeds. Here we develop two different strategies and compare their outcomes for simulated pedestrians. METHODS: 1) We determine a steady-state strategy for a biped walking on a laterally-oscillating platform using minimization of metabolic cost of transport. 2) We determine feedback control strategy using data from 'perturbation experiments' and apply this controller to humans walking on an oscillating platform. RESULTS: Minimization of metabolic cost of transport suggest that for a simple point-mass biped with massless legs, a) walking on a shaken platform (similar to a laterally oscillating treadmill) reduces energy costs below that of normal walking, and b) walking while shaking a shakeable platform (similar to a bridge or walkway) only reduces energy costs below normal if a sufficient number of people are walking on the bridge. These results suggest that energy optimality could explain why pedestrians walk in sync on a laterally oscillating platform, but do not accurately predict the critical number of pedestrians required to switch from a non-oscillating to an oscillating solution for bridges. We will present how a simple feedback controller to stabilize walking, when coupled to a shaking platform or a bridge, results in a wide-stepping walking behavior,

as seen in experiments. Through numerical simulations, we seek conditions under which a large number of pedestrians coupled together by a bridge will synchronize sufficiently to shake the bridge. CONCLUSIONS: Energy optimality on its own is sufficient to generate behavior similar to human beings in unusual scenarios such as walking on laterally shaking platforms even for simple point-mass models. A feedback controller based on walking stability might independently provide similar results. This work was supported in part by National Science Foundation grant no. 1254842.

P3-C-38 FES Control for Restoring Complex Functional Hindlimb Movements in the Rat

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Interventions to restore voluntary movement for patients with spinal cord injuries are limited. Functional electric stimulation (FES) of intact nerves or muscles can produce limb movements, but users' ability to control FES is minimal. We are examining the means to restore voluntary movement using cortically-controlled FES, in which a user's intended movements are estimated from cortical activity and then used to drive electrical stimulation of muscles. In previous work we have demonstrated that monkeys can use a cortically-controlled FES system to produce voluntary movements after a transient, nerve-block paralysis. The next step, application to actual spinal cord injury, is difficult in a monkey model. We are therefore developing a rat model of cortically-controlled FES with the ultimate goal of demonstrating the ability of this approach to restore voluntary locomotion after spinal cord injury. Within this larger goal, we are first establishing techniques for producing functional movements in the rat hindlimb. In previous work, we have demonstrated the ability to produce a range of endpoint forces through activation of multiple hindlimb muscles. We extend that work here in order to produce functional hindlimb movements, analogous to those produced during natural behavior. In preliminary experiments in a sedated rat, we stimulated flexors and extensors in isolation to produce simple unilateral locomotor movements. We used trains of stimulation (50Hz, 0.2-0.5ms, 1-4mA), alternately stimulating the flexor and extensor muscles at the hip, knee, and ankle to cycle the hindlimb through a smooth, repetitive stepping motion. We were able to control functional parameters of the evoked movements, such as step height and length, by varying the stimulation strength applied to individual muscles. These results demonstrate that our previous work showing good force control can be extended to the control of functional movements. In addition to controlling kinematic parameters of evoked movements, we will also measure ground-reaction and propulsive forces in order to demonstrate the feasibility of FES in a weight-bearing context. We will evaluate the consequences of increasing the

complexity of the commands applied to muscles, starting with simple alternation between flexors and extensors and then progressing to commands mimicking those observed from EMGs recorded during natural behaviors. We will also evaluate the minimal set of muscles that can be used to produce adequate control, and how muscle fatigue caused by repeated stimulation affects our ability to produce functional movements. These experiments will yield important information about the use of FES for the restoration of voluntary movement following spinal cord injury. This sophisticated degree of open-loop control of hindlimb motion is a necessary and significant step towards closed-loop control by the rat, achieved through cortically-controlled FES.

P3-C-39 Muscular reflex responses of trunk and lower limb muscles following unexpected gait perturbations in people with and without back pain

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BACKGROUND AND AIM: Poor neuromuscular control of the trunk has been identified in people with back pain. Altered muscle recruitment pattern and activation levels at the trunk were found in response to sudden loading situations. However, investigations were mostly restricted to isolated and quasi-static trunk loading experiments. It remains unclear, whether these alterations are limited to the trunk in more functional situations e.g. when sudden loadings are initiated via the extremities. Therefore, this study aimed to investigate muscular reflex responses at the trunk and lower limbs following unexpected gait perturbations in people with and without back pain. METHODS: 25 subjects with back pain (BP; 9 males, 16 females; 31±9 yrs; 73±14 kg; 1.75±0.12 m; characteristic pain intensity scale ≥30 (out of the graded chronic pain scale; von Korff)) and 29 asymptomatic controls (CTRL; 13 males, 16 females; 26±7 yrs; 72±12 kg; 1.75±0.11 m; characteristic pain intensity scale ≤10) were measured in a cross-sectional study design. Following a familiarization to treadmill walking (1 m/s; 5 min; unperturbed gait), all subjects underwent an eight minute perturbation protocol on a split-belt treadmill releasing 15 superimposed right-sided perturbations (deceleration, 40 m/s2, 50 ms duration; 200 ms after initial heel contact). Surface EMG of the trunk was recorded from 12 trunk muscles (right/left): rectus abdominus, obliquus externus/internus, latissimus dorsi, erector spinae at level L3 and Th9. Surface EMG of the lower extremities was recorded from 4 leg muscles (right): vastus medialis, biceps femoris, peroneus longus and tibialis anterior. For data analysis muscles were pooled into four trunk groups: ventral left (VL), ventral right (VR), dorsal left (DL), dorsal right (DR); and 2 leg groups (right side): upper leg (UL) and lower leg (LL). Latencies [ms] of muscular activity in response to perturbations were analyzed descriptively (mean ± SD) and tested by multiple analysis of

variance (MANOVA, α=.05) between BP and CTRL. RESULTS: EMG latencies reached in mean 93±10 ms at the trunk for BP and 85±7 ms for CTRL, whereas latencies at the leg showed in mean 83±1 ms for BP and 79±4 ms for CTRL. Latencies were longer in BP compared to CTRL in all muscle groups. However, statistically significant differences (MANOVA, p<.05) were only found for the trunk at VL (p<.01), VR (p<.01) and DR (p<.05). CONCLUSIONS: People with back pain revealed altered muscular reflex activities in response to sudden loadings during gait. Though perturbations were initiated by lower extremities, delayed muscle activations were exclusively evident at the trunk. These findings may indicate that muscular reflex activities are predominantly altered at the area of pain in people with back pain. Thereby, rehabilitation of back pain should especially target neuromuscular control of the trunk.

P3-C-40 Impact of neck muscle fatigue on scapulohumeral kinematics in subclinical neck pain pain vs asymptomatic controls

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BACKGROUND: The cervical spine and shoulder girdle are linked structurally and functionally. Scapular orientation is highly dependent upon functioning of the axioscapular musculature, and impairments in these muscles can lead to scapular dyskinesia. It is well documented that chronic neck pain (CNP) patients exhibit dysfunction in cervical spine biomechanics and motor patterns. However, to date the effects of CNP on scapulohumeral kinematics has had limited investigation. Previous studies are also limited because they constrained the shoulder movement to single plane, making it hard to determine if there are differences in shoulder kinematics when participants move naturally, without imposed constraints. We hypothesized that pain in the cervical spine could lead to alteration in the kinematics of the shoulder girdle and that fatigue would alter kinematics in the healthy group to a greater degree than in the neck pain group. METHODS: A three-dimensional analysis of scapulohumeral kinematics was performed during three repetitions of an arm elevation task to approximately 120 degrees in the scapular plane (35-40 degrees anterior to the coronal plane) performed at the participant's self-selected pace in 10 CNP participants and 10 healthy controls. Fatigue of the cervical extensor muscles was induced using repetitive, submaximal isometric contractions (6 s repetitions including 1 second ramp up, 3 s hold at 70% of maximal voluntary effort, and a 2 second rest). RESULTS: There were significant baseline differences in humeral elevation angle between healthy and CNP participants. The pre-fatigue kinematics also differed between the two groups. During humeral elevation, control participants start more purely in abduction in the first phases of the movement and this continues in the middle phases; whereas in the final phases, the humerus moved more into flexion. In contrast, humeral elevation angle for the CNP group stayed constant in the first and middle phases; moving more toward flexion, similar to controls only in the final phase. The CNP group also displayed less lateral scapular rotation, posterior scapular tilt and external scapular rotation relative to control group throughout humeral abduction. Fatigue significantly altered humeral elevation angle for the healthy group, with no significant effects on the CNP group. Fatigue caused the healthy group to start with the humerus in a more abducted position, while the CNP did not change significantly from the pre-fatigue state. DISCUSSION: Mild to moderate neck pain alters shoulder kinematics, due at least in part to altered scapulo-humeral coupling. The scapular kinematics seen in the CNP group are similar to those in patients with sub-acromial impingement, suggesting that CNP may be a risk factor for shoulder conditions. As hypothesized fatigue impacted shoulder kinematics more in healthy participants, possibly because CNP leads to similar neuromuscular compensations as fatigue.

P3-C-41 Joint learning during dyadic haptic interaction

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BACKGROUND AND AIM: In the last decade there has been a growing interest in studying physical coupling between humans or humans and machines. Having a machine capable of understanding the intention of a movement and interactively cooperate with a human is among the frontiers of the research in robotics as well as rehabilitation. Even if physical coupling between two subjects was shown to be an advantageous solution in many cooperative contexts, little is known about how two people mutually exchange information to exploit the coupling. This work investigated the ability of subjects to learn a novel skill and adapt their knowledge to a cooperative context that requires negotiating a common strategy while being physically coupled. The study mainly focuses on how learning develops in a context where training on a novel skill occurs in pairs. METHODS: We asked subjects to learn to jointly manipulate a compliant tool under the action of an unstable force-field, rendered by a haptic bimanual interface. The dynamics of the tool allows the dyads to select multiple control strategies to accomplish the task. In order to characterize the learning process in the dyad, we compared the case of two interacting individuals to one individual alone. To test the priming impact of an existing knowledge of the tool dynamics we considered the following experimental conditions: i) both the interacting subjects in the dyads have individually experienced the tool dynamics before (solo condition), ii) one of the subjects is an expert in the solo condition while the other lacks any previous experience, iii) one of the

subjects is an expert in the solo condition while the other has experienced the solo condition. The subjects practiced a reaching task for 4 days. On the fifth day we evaluated the ability of each dyad to perform a tracking task and the reaching task in the solo condition. The former task aimed at testing if the acquired skill could be generalized to a novel task. The latter served to evaluate whether the shared internal representation of the task could be sufficiently accurate to allow for a solo execution. The analyses were conducted on the end-effector kinematics and the electromyographic signals from 10 relevant muscles of the arm and trunk. RESULTS:The results show that the initial skill level has a strong impact on the development of a correct representation of the dynamics of the task. In particular the interaction with an expert in the absence of prior experience is detrimental. Conversely, having previously experienced the task dynamics unbiased by the action of the partner leads to the greatest performance benefit among the tested conditions. CONCLUSIONS:Skill learning in a shared context is possible and can be exploited by the individual. However, in contrast with what previously reported, physical interactions are not always beneficial to the performance of the interacting individuals, which appears to be strictly dependent on prior experience.

P3-C-42 Effects of a compression garment on sensory feedback transmission in the upper limb

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BACKGROUND AND AIM: Cutaneous feedback from the skin provides perceptual information about joint position and movement. Integrated with other sensory modalities, cutaneous feedback informs judgements of position and movement around joints. Currently, it remains unknown if a constant tactile input via compression apparel can alter excitability of muscle afferent feedback. Thus, the purpose of the current experiment was to: 1) Examine if sustained input to the skin via compression garment modulates sensory feedback transmission in the upper limb. 2) Examine if altered transmission is task or phase dependent and accompanied by improved task performance. METHODS: On separate days, neurologically intact participants completed two distinct parts of the experiment. Each part was completed under two conditions: CONTROL (no compression), and COMPRESSION (customized compression sleeve applied across the elbow joint). In both parts of the experiment, electromyography (EMG) of the flexor and extensor carpi radialis (FCR and ECR) was assessed. Stimulation was provided to the median nerve (single 1-ms pulse) just proximal to the elbow to elicit H-reflexes in the FCR. In part 1, constant m-wave (motor response) matched h- reflexes and M-H recruitment curves were elicited during separate

trials at rest, 10% wrist flexion, superficial radial (SR) nerve conditioning during 10% wrist flexion, and distal median nerve (dMED) conditioning during 10% wrist flexion. Conditioning stimulation was provided 37 ms prior to median nerve stimulation above the elbow. Cutaneous reflexes were evoked during 10% wrist flexion via stimulation of the superficial radial (SR) and distal median (dMED) nerves (3xRT for 5x1 ms @ 300 Hz). In part 2, M-H recruitment curves and constant m-wave matched h-reflexes were elicited during 10% wrist flexion, during arm-cycling at 60rpm and during a discrete reaching task. Reflexes were assessed at two specific phases (3 and 6 o'clock) for both arm-cycling and discrete reaching. All responses were normalized to maximally evoked m-waves. RESULTS: Combined results from parts 1 and 2 suggests that constant tactile input to the skin via compression garment reduces the gain of sensory feedback transmission from muscle afferents. These effects appear regardless of conditioning input or movement task. Accuracy of reaching movements and determination of movement endpoint were improved while wearing the compression sleeve. CONCLUSIONS: These results are indicative of segmental changes in spinal reflex excitability independent from muscular changes or descending input. Providing compression around a joint appears to increase the precision and sensitivity of sensorimotor integration where the sleeve is applied.

P3-C-43 Human upright, postural control: Is sagital centre of mass location controlled to a prior?

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BACKGROUND AND AIM: Posture is generally considered a flexible resource to be adapted as required. Furthermore, in symmetrical human standing, biomechanical mechanisms provide no stable sagittal location for the centre of mass relative to the ankle joints (CoMx). CoMx is biomechanically unstable with respect to the ankle and regulation of CoMx requires neural feedback control. Sensorimotor control is increasingly established as using Bayesian processes in which prior expectations stored in the nervous system are combined with online sensory input. We predict that the nervous system stores an expectation of the normal CoMx location and that posture is estimated and controlled in relation to that prior expectation. We define a prior as a pre-existing desired configuration of the body, which muscle activity is regulated to reproduce. With respect to CoMx the prior is defined as a statistical distribution (mean, standard deviation) which exists outside (before, during, after) the task and is reproduced consistently during task performance. METHODS: To test the hypothesis that CoMx is regulated to a stable prior fourteen participants participated in two tasks (free standing, and perturbed standing). Whole body movement was recorded (Vicon). We tested CoMx for significant difference between tasks. Free standing: Participants stood normally for

18 s after walking onto a force plate. Walking onto the force plate ensured the initial state had variable altered configuration. Two initial and two later repetitions were separated by the second perturbation experiment which, including setting up, occupied about 30 minutes. CoMx was sampled in three intervals (0-0.05 s, 0.6-5.6 s, 5.6-17.6 s). Perturbed standing: Participants stood for two trials of 210 s, each containing 32 gentle, discrete, asymetric, forward sagittal pulls, randomised in size, duration and leg (2-10 N, 0.2-2 s, right/left) that were delivered at the knee. The apparatus allowed unimpeded movement while standing quietly, could generate a sudden gentle force when required and provided no position information 1. CoMx was sampled prior to every perturbation. RESULTS: During free standing, after an initial positioning of the CoMx which was closer to the ankle joint centre, participants adopted a sustained location which differed from the initial locations but did not differ between repetitions or between tasks. By contrast, ankle dorsiflexion differed between tasks and head extension differed between repetitions of free standing. CONCLUSIONS: These results provide behavioural evidence for a prior sagittal location of the CoM stored within the nervous system and reproduced consistently between tasks and between repetitions of the standing tasks despite extended application of mechanical perturbations. 1 Di Giulio, Baltzopoulos, Managanaris & Loram. Human standing: Does the control strategy pre-program a rigid knee? J Appl Physiol, (2013)

P3-D-44 The effects of exercise in combination with other conventional antidepressant therapies in treating individuals suffering with Major Depressive Disorder.

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BACKGROUND AND AIM: Depression is currently the leading cause of disability worldwide and a leading contributor to disease burden globally. Existing antidepressant therapies are far from satisfactory leaving half of the depressed population undertreated. Research has found that exercise is an effective treatment for depression but it is not clear how and why it works. Brain-derived neurotrophic factor (BDNF) is growth factor and a candidate mechanism that has been shown to facilitate the effects of exercise on synaptic plasticity and cognitive function in rodents. The aim of this study is twofold: first, to investigate the additional benefits of an eight week exercise program in combination with other conventional therapies such as antidepressant medication and cognitive behavioural therapy (CBT) in improving

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depressive symptoms, anxiety and cognitive function in depressed individuals and second, to investigate the mechanisms associated with the antidepressant effects of exercise. METHODS: Sixteen participants with a clinical diagnosis of Major Depressive Disorder based on the DSM-IV and clinical interview were recruited from the Lakeridge Mental Health Day Treatment (LMHDT) program in Oshawa, Ontario. All participants were taking antidepressant medication for at least six weeks prior to study enrollment. Eight participants were assigned either to an eight week, supervised, moderate intensity exercise program plus CBT group or a CBT only group. Depression scores were determined using the Beck Depression Inventory (BDI), anxiety scores by the Hospital Anxiety Depression Scale (HADS) and recognition memory was determined using the Delayed Matching to Sample task from the Cambridge Neuropsychological Test Automated Battery (CANTAB). BDNF was quantified using participant plasma. All variables were measured at baseline and again at eight weeks. RESULTS: Following the eight weeks of treatment the exercise group showed a greater decrease in depression scores (169% vs 27%, p=.007). There was no significant difference in the decrease in anxiety scores between groups (27% vs 23%, p=.623). The exercise group showed a significant increase in plasma BDNF (p=.003) while the CBT only group showed no change. There were no significant changes in mean recognition memory in either group, however, the exercise group showed a greater decrease in the mean latency to make a correct response (p=.046) suggesting improved cognitive functioning. CONCLUSIONS: This project has the potential to provide a tool to improve exercise prescription, to predict exercise responders and to guide development of combined treatment approaches related to biochemical markers such as BDNF in order to optimize depression outcomes for Canadians.

P3-D-45 Effects of flexion-extension in upper and lower cervical spines on the laterality of upper and lower thoracic shapes

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[Purpose] Typical thoracic shape common to many people is bilaterally asymmetric as reported previously (Hirayama et al., 2013). Thoracic shape varies along with the movements of other parts like upper extremities and cervical region, and vice versa. When an asymmetrical thorax shape is fixed, motion of upper limb or cervical spine is reduced. Restricted cervical movements are often associated with thoracic malfunction, suggesting the presence of kinematic cervicothoracic coupling. We aim to investigate effects of segmental extension or flexion of upper and lower cervical spines on left and right thoracic cross-

sectional areas as representative of thoracic shape. [Methods] Subjects were 12 healthy men, 25.4±3.4 years old. Using 3-D analysis system (QM-3000, Topcon, Japan), the planer horizontal area at upper thorax (3rd limb level) or lower thorax (xiphoid level) were estimated at 5 cervical spine postures of the resting, the upper cervical spine extension and lower cervical spine extension position (UELE), the upper cervical spine flexion and lower cervical spine flexion (UFLF), the upper cervical spine extension position and lower cervical spine flexion (UELF), the upper cervical spine flexion and lower cervical spine extension positions (UFLE). The thorax planar area was divided into left and right by the center of sternum. We estimated lateral cross-sectional areas of the upper and lower thoraxes. Data analysis: paired t-test or two-way ANOVA. [Results] At resting, the cross sectional area at the upper thorax was significantly bigger in the left (7336.8, average in mm2) than the right (6804.8) ($p<0.05$). In contrast, at the lower thorax the right area (13750) was greater than the left (13266) ($p<0.05$), indicating the opposing relationship in asymmetry between upper and lower thoraxes. The bilateral differences in average values of planar areas in each directed posture were estimated: at the upper thorax, 114.4 (mm2) in UELE, 703.5 in UFLF, 704.5 in UELF and 133.1 in UFLE; and at the lower thorax, 129.7 in UELE, 606.2 in UFLF, 836.0 in UELF and 127.2 in UFLE. These changes in difference values suggest that the thoracic asymmetry was diminished upon extension of the lower cervical spine, but augmented upon its flection. Neither extension nor flection in the upper cervical spine affected the thoracic asymmetry. [Conclusion] Results indicate the cervicothoracic coupling with greater contribution of the lower cervical spine than the upper spine, leading to different changes between upper and lower thorax. Extension of lower cervical segment may straighten the thoracic spine and release the back muscle tension to help functional alignment of the rib, thereby diminishing the asymmetry of thoracic shapes to make the respiration easy. Flexion of lower cervical segment may twist the thoracic spine and heighten the back muscle tension to cause a malalignment of the rib, thereby increasing the asymmetry of thoracic shapes to make respiration obstructed.

P3-D-46 Effects of variation in trunk lateral deviation on respiratory function in relation to thicknesses of rectus abdominis and lateral abdominal group muscles

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Introduction/Background: Respiratory function is dependent on thoracic and trunk configurations. Rectus abdominis muscle (RA) and lateral abdominal muscles (LAs) affect the body trunk motion, thereby affecting respiration. Severe asymmetry in body trunk is observed in patients with respiratory dysfunction. Here we investigate the relation of asymmetry of muscle thicknesses (RA and LAs) or body trunk lateral area to respiratory function by deviating the body trunk position at supine to provide a better intervention for breathing problem. Materials and Methods: Subjects were 15 healthy men (27.6 ± 3.1 yo) and laid at supine on adjoining two beds. The border line of two beds perpendicularly crossed the body trunk at 12th rib. Sliding beds across the trunk axis made trunk shape either more bilaterally deviated or neutralized, in comparison with the intrinsically deviated shape of the trunk. Bilateral symmetric property was measured by estimating left and right areas of trunk back surface divided by the trunk axis captured by a digital camera. Using ultrasonography (Preirus, Hitachi), thicknesses of both left and right sides of RA at the center of the 3rd muscle compartment and LAs between the midpoint of the 10th rib lower end and pelvis were measured. Respiratory functions at resting and forced breathing were measured using gas analyzer (TV, MV and RR) and spirometer (VC, FVC, PEFR, %VC, and V25). Data were analyzed by paired t test or multiple comparison using SPSSver18J. Approved by the Ethnic Committee of Bunkyo Gakuin University. Results: At rest without bed sliding, the body trunk was asymmetrically deviated to the left: left area was 3.3% folds greater than right ($P<0.01$). When bed was slid to increase the body asymmetry to the left, muscle thicknesses of both RA and LAs became significantly smaller in the left than the right at the resting (both $P<0.01$) and forced breathing (both $P<0.05$). In contrast, when slid the bed to have bilaterally even trunk posture (neutralized posture), bilateral differences in muscle thicknesses of RA and LAs were abolished. In respiratory function, TV, RR, VC, FVC, PEFR, %VC and V25 were smaller at the increased asymmetric posture than the neutralized posture with bed sliding ($P<0.05$). While, FEV1.0 was smaller at the neutralized posture than the asymmetric posture ($P<0.05$). Conclusion: Results indicate that the increase in the leftward deviation of the trunk reduces RA and LAs thicknesses, being associated with the reduction in expiratory function. While, at the bilaterally even trunk posture, RA and LAs have bilaterally even thicknesses with the better breathing. At normal trunk posture most people have deviation in trunk slightly leftwards. COPD patients often possess severe deformation in trunk configuration both bilaterally and throcoabdominally (Priori et al., 2013). The severe respiratory dysfunction may be associated with the extensive bilateral deviation of the trunk as well as rib cage.

P3-D-47 Difference in the acute effect of kinesthetic illusion induced by visual stimulus and action observation on the upper-limb voluntary movement after stroke: a single-case study

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BACKGROUND AND AIM: Several studies have reported that induction of kinesthetic illusion by visual stimulus (KiNVIS) (Kaneko et al., 2007; Aoyama et al., 2012) and action observation (AO) (Fadiga et al., 1995) activates the motor cortex or corticospinal tract. KiNVIS could induce kinesthetic sensation in the subjects that their own limb is moving, even though the limb is actually in a resting state. We previously demonstrated the acute effect of KiNVIS on the movement function in stroke patients (Inada et al., ISEK, 2014). However, KiNVIS is apparently similar to AO while watching a movie, during which whether the acute effect is due to induction of KiNVIS or AO is unclear. Therefore, the aim of the present study was to clarify the difference in acute effect of KiNVIS and AO on the upper-limb voluntary movement after stroke. METHODS: The present study was approved by the local ethics committee. The subject was a 47-year-old man with a pons hemorrhage developed 19 weeks prior. The right upper-limb (UL) on the involved side could be flexed by the chest. Partial flexion and extension of the fingers was possible. Tactile sensation was slightly impaired on the UL. Cognition was not impaired. We adopted the ABA design. The interventions of visual stimulus were performed in the order of AO (AO-1), KiNVIS, and AO (AO-2) within a day. The intervention was executed after confirming that there was no effect of the latest intervention. The subject was instructed to watch a monitor, which displayed a movie that repeatedly showed an inverted non-paretic finger movement (flexion and extension) for 10 minutes. In AO, the monitor was placed in front of the subject. In KiNVIS, the monitor was placed on the subject's distal forearm to induce KiNVIS. Hand grip force was measured twice before intervention (pre-1, pre-2) and after each intervention. The subject was instructed to engage in 3 trials of maximal flexion of his finger. The greater of the value obtained for the hand grip force was used as the final hand grip force value. In addition, the subject was asked about the vividness of the illusory sensation by the visual stimulation. RESULTS: Hand grip forces were pre-1, 2.95 N; pre-2, 3.03 N; AO-1, 1.55 N; KiNVIS, 6.85 N; and AO-2, 1.97 N. Additionally, the subject reported vivid kinesthetic sensation of finger movement only after KiNVIS. CONCLUSIONS: This study demonstrated that hand grip force clearly increased after KiNVIS. Kaneko et al. (2015) showed that the motor-association areas of the frontoparietal cortex, insula, and striatum are more markedly activated during KiNVIS than during AO. Furthermore, the subject reported a strong feeling of moving his own finger while watching a movie that induced KiNVIS. Hence, we hypothesize that KiNVIS possibly promotes the upper-limb voluntary movement of the paretic finger after stroke.

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P3-D-48 ULNAR - Upper Limb fuNctional Assessment and Rehabilitation: tools and methods

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Upper limb movement characterization and functional analysis has not received the researchers attention, in the past decades, as much as gait analysis. However, in the case of post-stroke patients, the development of devices and methods that allow a more rapid and efficient evaluation of the condition of each patient is extremely important. Such evaluation would enable applying rehabilitation strategies without the presence of a therapist and significantly improve rehabilitation outcomes. In that way, it would be possible to assist in the assessment of the patient's condition, in the diagnosis and in the respective intervention in order to rehabilitate not only the ipsilesional limb but also avoid possibly harmful compensatory movements. The aim of this study is to develop a method based on concurrent motion analysis and EMG signal analysis to describe and compare the movement of participants without pathology with participants in stroke recovery.

P3-D-49 A comparison of three types of neuromuscular electrical stimulation for reducing contraction fatigue of the quadriceps muscles

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BACKGROUND AND AIM: Neuromuscular electrical stimulation (NMES) can produce contractions of paralyzed muscles to increase functionality and prevent or diminish secondary complications for people with spinal cord injury. Unfortunately, the benefits of NMES are limited by rapid contraction fatigue, which is due in large part to the non-physiological way that NMES produces contractions. Recently, we have found that alternating or "interleaving" NMES pulses (iNMES) between over a muscle belly (mNMES) and nerve trunk (nNMES) produces contractions that are more fatigue-resistant than mNMES and nNMES alone, at least for tibialis anterior (TA). In TA, mNMES preferentially recruits superficial motor units and nNMES recruits motor units more evenly throughout the muscle. Thus, iNMES recruits motor units from different portions of the muscle with every other stimulus pulse, reducing the discharge frequency of motor units by half, decreasing the metabolic demand of the recruited motor units and reducing contraction fatigue. Presently we studied contraction fatigability of the quadriceps muscles because they are the most

commonly stimulated muscles for NMES-based rehabilitation programs. We hypothesized that iNMES will produce quadriceps contractions that fatigue less than during mNMES and nNMES. METHODS: Six healthy human participants (3 Males and 3 females; ages 21 to 39; 24.6±7 years) were recruited. Each participant completed three sessions with the different types of NMES tested on separate days (iNMES, nNMES, and mNMES). Each session incorporated a fatigue protocol consisting of 170 contractions generated by NMES delivered at 40 Hz, with each contraction lasting 0.3 s and separated from the next contraction by 0.7 s. To determine if torque declined during each fatigue protocol the mean torque during the first five contractions was compared to the mean torque during the last five contractions. Contraction fatigue was calculated as the fatigue index (FI), by dividing the mean torque during the last five contractions by the mean torque during the first five contractions and multiplying by 100. Repeated measures analyzes of variance (rmANOVA) were performed to identify significant differences. RESULTS: Torque declined during the fatigue protocols in 6/6 participants during mNMES and iNMES. In contrast, torque declined in 4/6 participants during the nNMES fatigue protocol, however, it increased in the other 2 participants. Torque declined significantly only during the mNMES fatigue protocol (p=0.02). The FIs (mean + SD) for mNMES, nNMES, and iNMES were 60 ± 14.4, 117 ± 105.4 and 74 ± 18, respectively. There were no significant differences in FIs between the three types of NMES. CONCLUSION: The lack of a decline in torque during nNMES and iNMES may reflect the fact that transmission along central pathways may contribute to contractions produced by these types of NMES. The inclusion of more subjects to our sample is needed to increase the power of the study.

P3-D-50 Task-specific movements generated by EMG-FES facilitate cortical beta band modulation for hand rehabilitation in individuals with moderate to severe stroke.

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BACKGROUND AND AIM: Nearly 800,000 people experience a new or recurrent stroke each year, with only 20% regaining normal arm function within 3 months. Debilitating impairments, such as the inability to open the paretic hand, prevent this population from participating in activities of daily living. In mild acute cases of chronic stroke, the progressive repetition of task-specific hand/arm movements induces GABA-mediated plasticity and leads to sizable recovery in function. It has been found that such short-term decreases in GABA inhibition reduce beta band (13-30 Hz) power oscillations in sensorimotor areas just prior to movement, and facilitate cortical activity. Unfortunately, individuals with more severe

impairments cannot participate in task-specific training due to a lack of volitional control of the paretic hand, and thus we do not know its importance in this large population. To address this issue, our lab has developed a novel electromyography-driven functional electrical stimulation (EMG-FES) device (called the ReIn-Hand device) that allows individuals with moderate to severe stroke to produce electrically-assisted hand openings during functional reaching tasks. The current project aims to elucidate in a cross-sectional approach the importance of producing task-specific movements for generating beneficial cortical activity. METHODS: Two individuals with moderate to severe chronic stroke (S1 and S2) performed task-specific movements (i.e. reach to grasp a jar) and non task-specific movements (i.e. reach to open) using our ReIn-Hand system on a table. We recorded 160 channel high-density electroencephalography (EEG) during these movements, and calculated beta event-related desynchronization (ERD) prior to EMG onset. Additionally, we reconstructed the cortical activity just prior to EMG onset by calculating the inverse using Standardized low-resolution brain electromagnetic tomography (sLORETA). RESULTS: Both subjects showed increased beta ERD prior to task-specific movements (i.e. reach to grasp) compared to non task-specific movements (i.e. reach to open) over the contralateral sensorimotor area. Additionally, task-specific movements generated greater cortical activity in the contralateral primary motor cortex (M1). CONCLUSIONS: These preliminary results suggest that task-specific movements using EMG-FES generate greater modulation of contralateral cortical beta band oscillations compared to non task-specific movements in individuals with moderate to severe chronic stroke. In the future, a larger subject sample will be used to confirm this finding. Furthermore, we will investigate whether the generation of cortical activity could translate into long-term neural reorganization following a task-specific based EMG-FES intervention.

P3-D-51 Nintendo Wii decrease spasticity and improves standing balance in cerebral palsy

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BACKGROUND AND AIM: Spastic cerebral palsy (SCP) commonly presents neuromuscular alterations such as co-contraction, hypertonia and spasticity [1]. Spasticity is manifested by increased of stretch reflex, where a lack of modulation of the stretch reflex causes premature and/or exaggerated muscle contraction that may resist the passive stretch. Spasticity in the ankle plantarflexors can directly affecting the postural stability and standing balance [2]. The aim of the current study was to evaluate the effects of a Nintendo Wii exercise program on the ankle spasticity and the quiet standing balance in young people with SCP. METHODS:

Ten children and adolescents (aged 6-17 years) with SCP (6 hemiplegic, 3 diplegic y 1 monoplegic) participated in a exercise program with Nintendo Wii Balance Board (NWBB). The intervention lasted six weeks, 3 sessions per week, 25 minutes each session. Ankle spasticity was assessed using the Modified Modified Ashworth Scale (MMAS) [3], and quiet standing balance with center of pressure (COP) using a force platform (AMTI OR67) [4]. Baseline and post-intervention data were compared using paired t-test ($p \leq 0.05$). RESULTS: Participants show a significant spasticity decrease in the ankle plantiflexors ($p < 0.001$). Besides, decreased the area of COP sway (COPSway) ($p = 0.042$). CONCLUSIONS: This is the first report demonstrated that a six-weeks NWBB exercise program reduced the spasticity at the ankle plantiflexors and improved the quiet standing balance in young people with SCP. [1] Richards CL, Malouin F. Cerebral palsy: definition, assessment and rehabilitation. Handbook of Clinical Neurology 2012; 111: 183-195. [2] Bar-On et al. Spasticity and its contribution to hypertonia in cerebral palsy. BioMed Resarch International 2015; 2015: 317047. [3] Ghotbi et al. Measurement of lower-limb muscle spasticity: intrarater reliability of Modified Modified Ashworth Scale. Journal of Rehabilation Research & Development 2011; 48(1): 83-88. [4] Leach et al. Validating and calibrating the Nintendo Wii balance board to derive reliable center of pressure measures. Sensors 2014; 14(10): 18244-18267.

P3-D-52 Onset and cessation timing of seven lower limb muscles during walking in patients with diabetes with and without sensory neuropathy and persons without diabetes

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Background and aim. The aim of this study was to investigate the differences in onset and cessation timing of seven lower limb muscles during gait of participants with diabetes, with (PwDM_SNP) or without (PwDM) sensory neuropathy and asymptomatic adults (PwNoDM). Methods. Surface EMG recordings of rectus femoris, vastus lateralis, medial hamstrings, tibialis anterior, peroneus longus, soleus and lateral gastrocnemius of the three experimental groups were taken while walking at a self-selected speed. Each group consisted of thirteen age-, sex- and speed matched subjects. Onset and cessation timing for each participant and each muscle was determined through the application of the automated method described by Staude et al (2001). One-way ANOVA was applied to investigate differences between the three groups. Results. Both diabetes groups showed changes in muscle activation compared to the persons without diabetes, although not always significant. There were no significant differences in onset timing between the three groups. Cessation timing of the rectus femoris was significantly later in PwDM_SNP compared to PwDM and PwNoDM (table 1). Also cessation of the tibialis anterior was delayed in PwDM_SNP group compared to PwDM

(p=0.02) and PwNoDM (not significant). The peroneus longus on the other hand, showed a significant earlier cessation time in PwDM_SNP and PwDM compared to PwNoDM. Conclusions. Diabetes patients with and without sensory neuropathy demonstrate altered activation pattern of lower limb muscles during walking.

P3-D-53 Influence of using t-cane on variability of stride interval at a self-selected gait speed

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BACKGROUND AND AIM: Though human gait is highly stereotyped, the stride intervals fluctuate from one stride to the next. The variability of stride interval exhibits long-range temporal correlation. The variability of stride interval may be caused by a number of factors related to physical body and nervous system. Especially, the variability of stride interval was influenced by central nervous system based on integrative sensory feedback. It is not clear that whether the changes of dynamics of the stride interval produces or not with using t-cane. The purpose of this study was to examine the influence of using t-cane on the variability of stride interval at a self-selected gait speed. METHODS: Subjects were 20 healthy adult women (mean age = 21.5±1.2 years, height = 159.4±5 .6 cm, weight = 54±4 kg). After giving written informed consent, 20 healthy volunteers participated in this study. The subjects walked in three types of gait pattern on 20m walking path of 8-shaped line on floor for 10 minutes at their self-selected gait speed. The gait patterns were gait without t-cane, 2-point gait with t-cane, and 3-point gait with t-cane. All subjects were right-hand and right-foot dominant. They hold t-cane in their right hands at 2-point and 3-point gait. Time series data of the stride interval derived from four tri-axial accelerometers placed on seventh cervical vertebra, third lumbar vertebra, right heel, and left heel. Scaling exponent á and approximate entropy (ApEn, r = 0.2, m =2) were calculated from the time series data of stride interval (N = 600 strides) derived from each placed tri-axial accelerometer. Scaling exponent á and ApEn can quantify the long-range correlation and regularity of the time series data, respectively. Scaling exponent á and ApEn were compared using repeated measures analysis of variance with Shaffer's post hoc tests (R ver.2-8-1). Significant level was set at p < .05. RESULTS: Scaling exponent á of the time series data of stride intervals from the both heels at 2-point gait with t-cane was significantly lower than that at gait without t-cane. Scaling exponent á from the left heel at 3-point gait with t-cane was significantly lower than that at gait without t-cane, but scaling exponent á from the right heel at 3-point gait was not significantly lower. ApEn from both heel at 3-point gait was significantly lower than those of both at gait without t-cane and at 2-point gait. CONCLUSIONS: External cueing of using t-

cane may alter the temporal correlation structure of gait. Persistent long-range correlations in the stride intervals of self-paced gait may switch to anti-persistent correlations in the case of using t-cane. It was speculated that the decrease of the correlation and the increase of the regularity in the variability of stride interval at gait with t-cane resulted from being aware of the movement of gait with t-cane.

P3-D-54 Reproducibility of the motion generated by a master-slave system developed using neuromuscular electrical stimulation based on kinematic parameters

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<Purpose>We developed a master-slave system (KineStim) using neuromuscular electrical stimulation (NMES) based on kinematic parameters. KineStim consists of three processes: In process 1, we record the master motion and calculate the angles of the wrist joint and index finger using a three-dimensional motion analysis system (Vicon). In process 2, a program that we developed (KeSS) converts the kinematics parameters into NMES signals that are then transmitted to an electrical stimulation device. In process 3, the NMES signal, when applied to the extensor carpi radialis brevis muscle or extensor digitorum muscle, generates the slave motion in the wrist joint and index finger. KeSS consists of four programs. The first calculates the amplification needed to convert a joint angle into a NMES signal. The second extracts the joint angle calculated using Vicon. The third calculates the NMES intensity necessary to generate the slave motion. Finally, the fourth outputs the NMES intensity to the electrical stimulation device. The goal of this study was to examine the reproducibility of the motion generated by KineStim. <Method>Ten adult males participated as the subjects of this experiment. They were instructed to perform extension and flexion exercises with the right wrist and index finger, thus constituting the master motion. Sequences of exercise were constructed from four components: wrist extension from 0° to 30°, index finger extension from 0° to 30°, index finger flexion from 30° to 0°, and wrist flexion from 30° to 0°. Then, KineStim was used to generate the slave motion for the left arm. We recorded wrist and finger joint angles of the master and slave motions. After the completion of the experiment, we analyzed the reproducibility of the slave motion generated by KineStim, considering the cross-correlation coefficient and phase difference between the master and slave motions. <Result>The cross-correlation coefficients were 0.87 ± 0.12 for the wrist joint and 0.84 ± 0.19 for the index finger, with both exhibiting a strong correlation. The phase difference was 2.09 ± 1.05 s at the wrist joint and 1.04 ± 0.75 s at the index finger. <Discussion>The master and slave motions exhibited similar phases for both the wrist and index finger, but the slave motion was delayed relative to the master motion. The slave motion delay may be due to the

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difference between the minimum NMES intensity and the NMES intensity corresponding to the movement threshold when the NMES intensity increases. <Conclusion>KineStim proved capable of reproducing joint motion, but the slave motion was delayed relative to the master motion. However, given that clinical patients perform their exercises at low speeds, it may be possible to successfully apply KineStim to hemiplegia rehabilitation systems.

P3-D-55 Effect of Visual Feedback on Quality and Consistency of Upper Limb Movement in Stroke Patients

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Background and aim: Deficits in upper limb function often persist after stroke despite intensive motor rehabilitation. Feedback on movements has been suggested to improve motor skill reacquisition. A system for delivering visual feedback during upper limb training in sub-acute stroke patients is presented. Methods: Subjects moved the hand at self-paced speed within a rectangular pattern displayed on a 70 cm x 40 cm monitor embedded in a table under a 5 mm glass plate. The length and width of the pattern were set to 75% of the range of motion of the subject. The thickness of the rectangular pattern was preset to 50 mm. Movements were captured by a Kinect sensor mounted on a tripod above the table surface. Hand position was estimated by detecting a white colored LED, placed on the index finger of the more impaired hand, in the images captured by the Kinect sensor. The LED served as a reference point for the position of the hand during movement. A marker (filled circle) displayed 10 mm ahead of the detected position of the LED served as a guiding point on the monitor for the subjects during movement. The exercise was repeated up to 20 times by each subject. Seven stroke subjects (40-80y) participated in the experiment. In the feedback session, if the marker was kept within the pattern more than 90% of the time during one trial, the rectangular pattern thickness decreased in the following trial. If the hit rate dropped below 60%, the thickness increased. The thickness was changed in 10 mm increments/decrements within a range of 10-110 mm. If the centroid of the marker was within the rectangular pattern, the color of the marker stayed green. If the marker appeared outside the rectangular pattern, the marker color was changed: yellow if the distance was less than 15 mm and red when the distance exceeded 15 mm. Upon completion of each trial the marker trajectory was displayed to the subject. In the control session the thickness of the rectangular pattern stayed fixed at 50 mm, the color of the marker was displayed to the subject in blue, and the marker trajectories were not displayed to the subject after trials. Each subject participated in one control and one feedback session (randomized) on different days. Results: The mean performance time ± SD was statistically higher in the feedback session (43.2 ± 20.9 s) compared to the control session (27.0 ± 16.9 s). The mean movement

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variability ± SD was statistically lower in the feedback session (4.1 ± 1.4 mm) compared to the control session (6.1 ± 2.1 mm). Conclusions: These preliminary results showed that performance time increased and movement variability decreased when stroke subjects were presented with visual feedback. The first outcome implies that, when given the visual information about the performance, stroke patients were more motivated to fulfill the task, while the second result suggests that immediate motor relearning was initiated.

P3-D-56 Effects of augmented verbal feedback in the ankle electrical activity and torque of typical individuals

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BACKGROUND AND AIM: It is usual in physical therapy treatments and physical activity using verbal stimuli to encourage motor proposed activity. However, it is unclear whether the response to this stimulus may vary when we change the source of it. The aims is to determine the effect of verbal encouragement, as augmented feedback, in ankle maximum isometric torque and muscle activity of the tibialis anterior in typical individuals and verify the reliability of this method (inter and intra examiner). METHODS: Nineteen healthy volunteers (22.7±4.3yrs old) with no history of ankle surgery had their tibialis anterior myoelectric signal acquired by means of circular bipolar adhesive electrodes of Ag/AgCl (diameter=10mm, IED=20mm) while performing maximum voluntary contraction. EMG signals were sampled at 2kHz, then filtered by a 4th-order butterworth filter (10-500Hz) and amplified (gain=1000). The root-mean-square (RMS) of a 500ms window was calculated for each testing session. Ankle maximum flexion torque was assessed with an ankle dynamometer (ergometer OTBioelettronica) instrumented with a strain gage load cell with a capacity up to 1000 N. The subjects performed the test sitting on a chair properly adjustable, with knees flexed (<90 degrees), and with the ankle joint center positioned in alignment with the axis of the dynamometer. Four conditions regarding the use of verbal encouragement (VE) were set: two examiners (E1 and E2), their recorded voices (R1 and R2) and one condition without verbal encouragement (WVE). Each subject performed two attempts of maximum voluntary isometric ankle flexion. The conditions E1, R1 and WVE were repeated after 1 week. ANOVA for repeated measures was used to compare conditions, followed by Tukey HSD test (α=0.05), and Cohen's coefficients (d) were calculated between conditions to express the effect size obtained. Intraclass coefficients type 2,k and 3,k were calculated to verify reliability between examiners and sessions, respectively. RESULTS: No differences were found between all conditions in the first day of evaluation for ankle torque (p=0.787) and for

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tibialis anterior EMG (p=0.206). In the second day of evaluation, again no differences were found in ankle torque (p=0.341) and EMG (p=0.269). The reliability of E1 between day 1 and day 2 for EMG was ICC3,k=0.94 and repeatability between E1 and E2 was ICC2,k=0.94. For maximum flexion torque, E1 reliability resulted an ICC3,k=0.87 and between examiners an ICC2,k of 0.98 was obtained (Table 1). Recorded voices or presential verbal encouragement did not influence in the EMG or torque measures. CONCLUSION: The isometric ankle torque was not influenced by any verbal encouragement: neither presential nor recorded voice. These results shows an important aspect from this assessment very used by researchers. Our results also showed a very good reliability of EMG and torque measures using verbal encouragement between session and between examiners.

P3-E-57 Influence of the mandibular tori in the stomatognathic system function

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BACKGROUND AND AIM: The mandibular tori is a convex bony growth, well-defined, with a dense cortical covered by a thin mucosa, poorly irrigated, with multifactorial etiology, attributed to genetic and environmental factors, masticatory hyperfunction, and slowly growing throughout life. This research evaluated the effects of mandibular tori on stomatognathic system through EMG activity of masseter and temporalis muscles. METHODS: Participants 40 individuals, divided into two groups: with mandibular tori (GI, n=20) and without mandibular tori (GII, n=20). The Myosystem-Br1 electromyography was used to analyze electromyographic (EMG) activity. This study was previously approved by the Research Ethics Committee of the State University of Montes Claros/Minas Gerais/Brazil (case number 226/704). The Myosystem-Br1 electromyography was used to analyze electromyographic (EMG) activity. Assessment of muscle activity was performed by EMG recordings of the right masseter (RM), left masseter (LM), right temporal (RT) and left temporal (LT) muscles, during postural rest condition, clenching in maximum voluntary contraction, maximum right and left laterality with dental contact and maximum protrusion with dental contact. The data were tabulated and subjected to statistical analysis using independent t test (SPSS 19.0). RESULTS: The EMG analysis in the condition of the mandibular at rest showed minimal electrical activity in all of the muscles evaluated in both groups. It was also found one electromyographic hyperactivity of the masseter muscles of patients with mandibular tori during postural condition of protrusion, clenching in maximum voluntary contraction and teeth clenching with parafilm (p <0.05). In lateralities there was

also a greater electromyographic activity in individuals with Toro, and this difference was significant (p <0.05) in the left masseter during the right laterality and in the right masseter during left laterality. For chewing, it was found electromyographic hyperactivity of the masseter and temporal muscles of patients with mandibular tori (p <0.01). CONCLUSION: A Based on the results it can be concluded that mandibular tori is associated with functional changes in the stomatognathic system. ACKNOWLEDGEMENT: FAPESP and CNPq

P3-E-58 Latissimus dorsi, maximus gluteus and biceps femoris activation in people with sacroiliac joint dysfunction

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BACKGROUND AND AIM: It has been established that the sacroiliac joint dysfunction (SIJD) can explain 15% to 30% of the idiopathic cases of low back pain (LBP). This dysfunction may be secondary to muscle weakness which provides stability to the sacroiliac joint (SIJ) through its interaction with the thoracolumbar fascia (TLF), such as the latissimus dorsi (LD), gluteus maximus (GM) and biceps femoris (BF). According to this stabilizing capacity, it is considered that the deficit in its role would be a trigger for SIJD. The pattern of activation and recruitment of those muscles during dynamic activities, such as lifting a load from ground level, has not been evaluated in people with SIJD. Therefore, the aim of this study is to compare the electromyographic (EMG) behavior of LD, GM and BF in people with LBP, and LBP combined with SIJD during lifting a load from ground level. METHODS: descriptive observational study. Each participant performed one trial lifting with each lower limb, starting from the standing position where feet were kept together. EMG was simultaneously recorded for all muscles. A load cell on the ground was used to identify the start and end of the activity. The EMG was normalized by submaximal voluntary contraction (SVC). The signal processing was performed using MATLAB. The variables were: Root Mean Square (RMS) amplitude and latency. The EMG recording was performed in the beginning of the evaluation. Six pain provocation tests were performed in the end in order to establish the presence or absence of SIJD. Obeying the distribution of variables, comparisons between groups were established by student t test. RESULTS: A total of 15 subjects with low back pain, both genders, aging 31.5±12.81 years, height 167.2±11.26 cm and weight 73.2±17.30 kg were included. Nine subjects in LBP group and six in the LBP/SIJD group. Electrical muscle activation did not show significant differences between groups. However, LBP/SIJD group had a delay in activation. Negative latencies were found in all muscles when the task was performed with both right and left lower limbs. In addition, the BF amplitude was higher (5.72±1.06%SVC) while the GM was low (4.00±0.78%SVC) when the LBP/SIJD group performed the activity with the right lower limb. When the LBP group performed the activity

with the same limb the amplitude was higher in GM (5.23±0.58%SVC) while the BF was low (4.77±0.85%SVC). It suggests a possible compensation to achieve stabilization of the SIJ in the LBP/SIJD group. CONCLUSIONS: The delay in EMG activation of muscles on the supporting side while lifting in subjects with SIJD suggests a change in the stabilizing strategy that might disrupt the charge transfer through the pelvis, and increase the presence of low back pain in these subjects.

P3-E-59 Subject-specific classification of startle elicited by postural perturbation

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SIGNIFICANCE: Postural perturbations elicit many complex motor responses. These rapid motor responses are essential to our ability to safely and appropriately respond to disturbances during many everyday tasks, such as recovering from tripping or being bumped by a passerby. Recent evidence suggests one such rapid motor response, the release of a movement plan, involves activation of startle-related brainstem pathways. The sternocleidomastoid (SCM) muscle is often used as a physiological marker of brainstem activity; however, in the response to postural perturbations its use is confounded by the role of the SCM in neck stabilization. AIM: To develop a methodology that distinguishes SCM activity involved in neck stabilization from that elicited by postural perturbations thought to activate startle-related pathways in the brainstem. METHODS: Data were collected from 12 healthy subjects as part of a separate physiological experiment examining the response to postural perturbations delivered prior to reaching. Subjects were seated with the right arm attached to a rotary motor used to apply perturbations. Each trial began with an auditory WARNING tone, cueing the subject to prepare a ballistic elbow extension movement, followed by the GO cue, a small 10°/s, 100 ms elbow flexion perturbation. The time between WARNING and GO cues was uniformly distributed between 2.5-3.5 s. Perturbations of 100°/s, also lasting for 100 ms, were presented in 20% of the trials either before the WARNING or at various times before the GO to probe the motor system. Rectified EMGs recorded from the left SCM muscle were displayed on a trial-by-trial basis. Onset was marked as the first sustained rise of EMG, filtered using a 25 ms centered moving average, three standard deviations above background activity. Onsets were then manually reviewed and adjusted to the initial rise of unfiltered EMG from background activity. A subject-specific cutoff time to classify startle-related SCM activation was identified as the 5th percentile of SCM onset for neck stabilization during volitional reaching cued by a postural perturbation. A trial with SCM activity prior to the cutoff time was classified as SCM+. A trial without the presence of SCM activity or with activity later than the cutoff was classified as SCM-. Response classification was compared to a fixed cutoff time of 120 ms which is commonly used to indicate startle-related activity in the literature. RESULTS: The lower limit of SCM onset for neck stabilization determined using the 5th percentile of onset during voluntary reaching was 96.8 ms (range: 78.0-111.4 ms). The use of this subject-specific cutoff time improved the classification of startle-related SCM activity compared to the commonly used cutoff of 120 ms which classified 83.5% (range: 35.7-100%) of volitional trials as startle responses. CONCLUSIONS: Common methods for using the activity of SCM muscles as an indicator of startle can lead to misclassifications in experiments that also require these muscles to be used for neck stabilization. In these cases, subject-specific criteria that considers volitional activation can lead to a more selective classification. ACKNOWLEDGEMENT: Funding provided by NIH R01 NS053813 and T32 EB009406.

P3-E-60 Analysis of electromyographic fatigue of masticatory muscles in osteoporotic individuals

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AIM: Osteoporosis is a skeletal progressive and chronic disease in which there is a loss of bone mass, reducing its strength and predisposing the fractures, especially in regions of the wrist, hip and spine. It also affects facial bones, such as the maxilla and mandible. This research evaluated the electromyographic fatigue threshold of masticatory muscles in osteoporotic individuals. METHODS: 24 individuals aged between 45 and 70 years, of both genders and with osteoporosis. They were submitted to electromyographic evaluation in right masseter (RM), left masseter (LM), right temporalis (RT) and left temporalis (LT) muscles in the clinical conditions of maximum voluntary contraction for 4 seconds and muscle fatigue during a constant force isometric contraction. The EMG analysis was performed using the Myosystem-Br1 apparatus. The analyses of the median frequency EMG signal data were standardized obtaining the values obtained from the select windows of 5 seconds length duration at initial time (IT), medium time (MT) and final time (FT) of total length duration of each analysis. It was performed statistical analysis using ANOVA (SPSS 22.0). The Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo, previously approved this study. RESULTS: During the clinical condition of muscle fatigue in the medium and final times it was found a progressive decrease of median frequency when compared with the 5 seconds initial, for all evaluated muscles. The values of median frequency were significantly lower for temporalis muscles ($P \leq 0.05$). CONCLUSION: According to the results of this research it can be concluded that osteoporotic individuals show

changes in fatigue levels in the evaluated muscles. ACKNOWLEDGEMENT: This study was supported by FAPESP and CNPq.

P3-E-61 EMG analysis of cervical muscles after acupuncture in women with dysfunction temporomandibular

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BACKGROUND AND AIM: The temporomandibular dysfunction (TMD) is a multifactorial myofunctional disorder that affects the stomatognathic system. Among the most common signs and symptoms are both myofascial and neck pain. Acupuncture is a therapeutic resource that relieves and treat these painful symptoms. This research evaluated by EMG activity and pressure pain threshold (PPT) the right sternocleidomastoid (RECOM), left sternocleidomastoid (LECOM), right trapezius (RT) and left trapezius (LT) of women with muscular TMD submitted to acupuncture treatment. METHODS: 25 women (aged 18 to 50 years) were evaluated and diagnosed with muscular TMD (DC/TMD), also complaining of pain in the cervical muscles. Underwent initial evaluation (I), prior to treatment with acupuncture, EMG activity (Myosystem-Br1 v3,5) and pressure pain threshold (digital algometer). The conditions analyzed in the EMG activity were: postural rest (4s), maximal voluntary contraction (4s), neck rotation to the right (4s), neck rotation to the left (4s), elevation of the shoulders (4s) crucifix (4s). Acupuncture treatment was performed in 10 sessions, 02 times a week, lasting 30 minutes each session. The treatment protocol for acupuncture was: local spots (E6, E7, ID18, ID19, VB20, VB14, TA17, HN3, VG26) and points distance (F3, B60, BP6, E36, VB34, IG4). The needles dimensions used were 0.25 diameter x 0.30 (Dong Bang). Final evaluations were performed after 15 days after treatment with acupuncture (II). The EMG values were normalized by teeth clenching in maximal voluntary contraction (4s). The average EMG and the LDP were tabulated and submitted to statistical analysis by the independent t-test (SPSS 21.0). This research was approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo. RESULTS: EMG activity was significant ($P < 0.05$) for lifting shoulders: LT = [(I = 5.53 ± 0.61), (II = 24.4 ± 0.46)]; neck rotation to the right: LECOM = [(I = 4.98 ± 0.82), (II = 6.50 ± 0.96)]. The LDP was significant ($P < 0.05$): RECOM = [(I = 1.35 ± 0.14) (II =1.80 ± 0.13)] LECOM = [(I = 1.43 ± 0.07), (II = 1.70 ± 0.10)] RT = [(I = 1.90 ± 0.19), (II =3.00 ± 0.16)] and LT = [(I = 1.99 ± 0.14), (II = 3.13 ± 0.17)]. CONCLUSION: Based on the results of this research, it can be concluded that treatment with acupuncture was able to alter the activity of the cervical

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muscles and increase the pain threshold to pressure from women with muscular TMD.
ACKNOWLEDGEMENT: FAPESP, CNPq and CAPES

P3-E-62 Assessing muscular activation of patients with specific low back pain during daily activities

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BACKGROUND: Due to the growing number of people with specific low back pain and the associated costs the question arises whether there is a cost-efficient and effective treatment approach. Conservative treatment measures, especially with supportive orthoses or bandages, are often rejected, because they are suspected of weakening the muscles. Information on the physiological activation of back and abdomen muscles during daily activities is heterogeneous in literature. This might be because activities of daily living are difficult to analyze due to their complexity. sEMG envelope, often used to assess muscular activation during movements, depends on several biomechanical factors like trunk position, movement velocity or contraction type, all of which are hard to control during daily activities. The aim of this paper is to introduce a procedure, which allows a systematical assessment of the muscular activation of back and abdomen muscles during activities of daily living with relevance for patients with specific low back pain. METHOD: 20 patients with specific low back pain were asked about tasks of daily living causing pain. From that survey five movement tasks were identified as hampering the patients during their daily live. An exercise course of different assistive devices has been developed, in which the five movement tasks can be performed freely by the subjects in their individual movement rhythm and velocity. Trunk position, movement speed and direction of movement during these specific exercises were detected by sensors embedded in the devices. sEMG was recorded from m. erector spinae iliocostalis, m. erector spinae longissimus and m. obliqus externus abdominis synchronously to the sensor information. The sEMG signals were normalized and the sEMG envelope was generated for each channel. Based on the sensor data of the devices, sEMG of each muscle was categorized into groups of similar movement velocity, trunk position and movement direction in order to minimize the influence of movement dynamics on the results. 20 healthy subjects and 10 patients with specific low back pain took part in the study. RESULTS: The variation of sEMG envelope during exercises with healthy subjects decreased when subcategorizing the exercises with regards to trunk position, movement speed and movement direction. Additionally, reproducibility was improved. Patients with specific low back pain were able to complete the exercise course and showed differences in muscular activation.CONCLUSION: The overall procedure allows the systematical assessment of muscular activation in movement tasks of daily living, which are of relevance for patients.

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Although the movements are performed by the subjects in their individual movement-rhythm and velocity, comparability was achieved by categorization. This forms the basis for systematic analysis of the differences in muscular activation of patients with specific low back pain in larger groups and in different centers.

P3-E-63 Linear and Rotational Acceleration of the Head on Snowboard Beginner's Falls during Freestyle Snowboarding

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BACKGROUND AND AIM: The mechanism of injury causes in sports is categorized into two major patterns. One is that actions such as failure in jumping, falls or collisions provoke high energy injury derived from massive impact to the head in translational motion. This conceivably causes severe head injury such as cranial bone fracture and cerebral contusion. The other is that massive rotational acceleration to the head driven by a fall generates a shear deformation between the cerebrum and the endocranium that possibly causes acute subdural hematoma. Therefore, the linear and rotational acceleration of the head function as a parameter to meaningfully measure the injury severity. The objective of this study was to examine the linear and rotational acceleration of the head when falling and to analyse and establish precise evaluation and effective prevention upon head injury of snowboarders. METHODS: The male at beginner level in snowboarding was selected as a participant. Various patterns of falls in freestyle snowboarding were filmed in the slope with an angle of 10 degrees. The fall patterns were defined as follows: a fall in which a snowboarder failed to switch his board's edge from the toe side to the heel side causing a forward lean onto the lower side of the slope was named forward fall, whilst the inverse pattern was named backward fall. RESULTS: The reverse-edge phenomenon in snowboarding is well-known to trigger off severe head injury. The results of this study indicate that the peak values in angular acceleration in rotary motion on the frontal-horizontal axis tended to be larger in backward fall. Since the mechanism of a typical backward fall generated increase in angular velocity of the head in reverse-edge snowboarding, head's rotary movement on the frontal-horizontal axis was assumed harmful. As linear and rotational acceleration increase brain pressure and its motion are activated. The peak value in angular acceleration recorded less than 1,000 rad・s-2, hence were it not for organic issues the risk causing severe head injury is disproved under the condition of this research "falls performed by a snowboard beginner on the gentle slope". The value of the force on the head at its lowest position used as an indicator of impact to the head was 236 (101.7) kg・m・s-2 on the frontal-horizontal axis. As compared to the one demonstrated in exemplary throws of judo; 240 (19.95) kg・m・s-2, the value was not considerable. Therefore, the finding indicates that impact to the head was not considered remarkable when snowboard beginners fall onto the gentle slope during their practice. CONCLUSIONS: When a snowboard beginner falls during freestyle snowboarding, kinematic displacement of the head was observed dissimilarly depending on fall patterns. Further research should enlarge the number of analyses of fall patterns in freestyle snowboarding or jump motion and investigate the risk threshold of kinematic parameters of each body part, especially the head.

P3-E-64 Relationship between co-contraction ratio and knee adduction moment in knee osteoarthritis subjects

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Background and Aim: Knee osteoarthritis (KOA) is strongly associated with knee load and the KAM has been used as a predictor of medial knee load. In addition, higher co-contraction ratio has been observed in KOA subjects and identified as one of the possible reasons for the increased medial knee load. The aim of this study was to investigate the relationship between co-contraction ratio and knee adduction moment in KOA subjects. Methods: Twenty-five subjects diagnosed with KOA were included in the study. They were underwent a three-dimensional gait analysis at self-selected speed. The co-contraction was measured using Heinden et al. (2009) method for the follow ratios: VM:MG, VL:LG, VL:BF, EXT(VM,VL,RF):FLX(BF,MG,LG), QUA(VM, VL):GAST(MG, LG). In order to process the correlation measurements we used the KAM during the stance phase, first and second peak. Results: A significant correlation was found between the co-contraction ratio VL:BF and knee adduction moment during stance phase (r = -0.54, p=0.01), first peak (r = -0.61, p=0.01) and second peak (r = -0.58, p = 0.01). Conclusions: Considering our findings, the co-contraction ratio VL:BF might be considered in future studies to better understand the behaviour of knee medial load compartment, mainly with treatment approach in KOA subjects.

P3-E-65 Quantification of head movement when testing segmental trunk control

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BACKGROUND AND AIM: Trunk control is fundamental for effective functional activity in neuromotor disability [1]. In contrast to other subjective tests that consider the trunk as a single unit the Segmental Assessment of Trunk Control (SATCo) assesses discrete segmental levels [2]. Furthermore, the SATCo includes Static, Active and Reactive control giving a more complete picture. The SATCo is conducted in sitting with firm horizontal support directly beneath the tested trunk segment. It tests six segmental levels (Head through Lower Lumbar) and free sitting. This study measured Head motion during a SATCo to give an objective quantification of a subjective assessment. METHODS: One healthy adult (27y) and two children with different degrees of neuromuscular disability (4y1m, 4y5m) were tested using the SATCo. Child 1 was learning to control his trunk without external support. Child 2 was learning to control his trunk with external support at waist level. A video camera additionally recorded sagittal plane movements. Markers were placed on the ear tragus and temporal fossa in vertical line with the ear when the head was aligned. These were used to define a Head segment. Head segmental angles were calculated in relation to a real vertical. Cumulative displacement from the vertical normalised by time was calculated for each trial. RESULTS: Head motion during testing of Upper-Thoracic (UT) and Lower-Lumbar (LL) segments are shown in Figure 1. As expected, the Adult showed only small Head displacement throughout. Larger values for the Reactive tests are a clear indication that Child 1 is still acquiring full trunk control. The poor lumbar control of Child 2 is clearly demonstrated and contrasts with Child 1 for the Active and the Reactive tests. CONCLUSION: The results show how increasing task complexity (Static to Reactive) and reducing the level of segmental support (UT to LL), increases Head motion in the presence of a neuromotor disability. This is consistent with the subjective valuation of the SATCo. Previous studies have quantified Head motion of typically developing children in relation to the level of support during quiet sitting [3, 4] showing 2.3°/s for unsupported sitting [3] and 18° for thoracic support and 30° for pelvic support [4]. However, the methods used by Curtis [3](3D motion capture system) and Rachwani [4] (magnetic tracking sensor) are difficult and costly to use in a clinical setting. Our video based method is clinically practical with minimal disrruption to the clinical session. Quantification of an assessment complements the subjective findings and provides validation for any changes observed over time. REFERENCES: [1] Curtis D. 2014. Developmental Medicine and Child Neurology [2] Butler P. 2010. Pediatric Physical Therapy [3] Curtis D. 2015. Journal of Motor Behaviour [4] Rachwani J. 2013. Experimental Brain Research

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P3-E-66 Impact of rheumatoid arthritis in stomatognathic system of the women

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BACKGROUND AND AIM: Rheumatoid arthritis is a serious disease that considered may influence the quality of human life, characterized by signs and symptoms such as fever, malaise, weakness, pain, swelling, warmth, redness in any joint in the body, morning stiffness, fatigue , limitation of movement and destruction of articular cartilage. This research evaluated the effects of rheumatoid arthritis on stomatognathic system through EMG activity of masseter and temporalis muscles and maximum molar bite force. METHODS: 16 women with natural dentition (aged between 40 and 60 years) were divided into two groups: GI: rheumatoid arthritis (n=8, average age 51.50 ± 3.12 years) e GII: healthy control (n=8, average age 50.75 ± 3.18 years). The groups were matched subject to subject by age and body mass index. GI presented discomfort in the preauricular region, normal mandibular mobility, and absence of popping, clicking or grinding sounds in the temporomandibular joint. This study was previously approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo. Assessment of muscle activity was performed by EMG recordings of the right masseter (RM), left masseter (LM), right temporal (RT) and left temporal (LT) muscles, during postural rest condition (4s), clenching in maximum voluntary contraction (4s), maximum right and left laterality with dental contact (10s) and maximum protrusion with dental contact (10s). Surface EMG was performed using TrignoTM Wireless EMG System Delsys. Kratos digital dynamometer was used to analyze right and left maximum molar bite force. The values were normalized by of the EMG signal of maximum dental clenching (4s). The EMG and bite force means were tabulated and subjected to statistical analysis using independent t test (SPSS 21.0). RESULTS: EMG activity was significant ($P < 0.05$) for mandibular rest: RM= [(I = 0.24 ± 0.04), (II=0.09 ± 0.02)]; RT= [(I = 0.34 ± 0.04), (II=0.20 ± 0.03)]; protrusion: RT= [(I = 0.34 ± 0.03), (II=0.18 ± 0.03)]. The values maximum molar bite force (N) was significant ($P < 0.05$) for right region= [(I = 147.88 ± 2.44), (II = 220.84 ± 2.58)] and left region = [(I = 125.23 ± 2.68), (II = 215.05 ± 2.92)]. CONCLUSION: Based on the results of this research, it can be concluded that adult women with rheumatoid arthritis showed changes to the stomatognathic system, especially concerning EMG activity and maximum molar bite force. ACKNOWLEDGEMENT: FAPESP and CNPq

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P3-K -67 The effect of carbohydrate supplementation to muscle fatigue trend in training of table tennis

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BACKGROUND: The recovery of muscle fatigue for carbohydrate and nutrient supplement after exercise has been well known that is important. However, actual sports must be a long time practice and maintaining the fitness level. Especially, table tennis must be a lot of practice for technology acquisition because there is a lot of technology. Therefore, maintenance of physical fitness level and performance in practice is important, to suppress the fatigue and recovery during training as well as after the practice. METHODS: This study was carried out in two methods at the same time. The first method was seen change in blood lactate concentration after the trial of muscle fatigue analysis experiment. The Second method was see muscle fatigue trend by the EMG analysis results. The subject belong to table tennis club of Niigata University. They all right-hander and they use pimples-in rubber on face of forehand. The electrodes were put on subject's biceps femoris muscles, vastus medialis muscles, and gastrocnemius muscles. The subjects wore goniometer to pick out a stroke with angle of elbow. Then, they did a stroke for a second and it continued for three minutes on trial. After taking a 15-minutes break, they did a trial again. Then, we did Fourier transform by the program was made with MATLAB R2014a(produced by Math Works) on condition that sampling frequency 1000Hz, section length 500msec, shift length 20sec. We got Average Rectified Value (ARV) to estimate muscle active mass, and Mean Power Frequency (MPF) to know information about frequency of muscle discharges. RESULTS: In the comparison of the blood lactate concentration and average exercise intensity, direction of fatigue suppression group was relatively lower number than the fatigue group. Therefore, the lactic acid concentration and EMG fatigue analysis in the blood had been suggested that relevant. The subject of fatigue suppression group's lactate threshold is higher than fatigue group because they have a high endurance. Also from a change in the blood lactate concentration, muscle fatigue suppression group was got the energy supply from the mainly aerobic system, the other hand muscle fatigue group was got mainly energy from glycolysis. CONCLUSIONS: The effect of carbohydrate supplementation to muscle fatigue is different each by the energy supply system and lactate threshold. If lactate threshold is high and mainly using aerobic system, carbohydrate replenishment is fully effective. It is possible to advice of training and carbohydrate supply by EMG analysis results and blood lactate concentration result.

P3-K -68 Influence of data precision on quantifying skeletal muscle movement in ultrasound images

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BACKGROUND AND AIM: Ultrasound (US) imaging is a well-recognised technique for studying static tissue, due to its portability, low cost and ease of use. The majority of commercially available US devices do not allow access to "raw data". Instead, RF data (radio frequency, unprocessed data collected from the US transducer) is post-processed, compressed and stored, most often to 8 bit precision (256 possible values). Many of the filters and compression algorithms employed are "black box", so the inner workings are not accessible, distorting data in an unknown manner. In an irreversible operation, a portion of RF data is lost during this process (lossy compression). As such, the only data available to many studying neuromuscular function are highly compressed and filtered video files. Some current generation US devices offer important features which make the RF data available to researchers. 10-16 bit data can now be accessed before filtering or compression is applied. This improvement allows access to higher resolution data, and allows users to apply their own post-processing, which may be adapted to their specific requirements. The potential value/advantages of the availability of such data has not however been widely investigated. Comparisons between RF and compressed data currently available have focused on the timing of events or pixel brightness rather than qualitative differences between data. The aim of this work is therefore to evaluate the effect of data compression on tracking muscle movements. METHODS: RF (12-14bit) and compressed (8bit) formats, were acquired from the medial gastrocnemius (MG) during active contractions (20, 50 and 80 % MVC) and joint rotations (4 and 8 degrees/s). Muscle movement in MG was quantified using a Kanade-Lucas-Tomasi feature tracking approach. A description of the joint torque as a first degree polynomial was estimated from the US movement information in a least-squares sense. As a result, Normalised Root Mean Square Error (NRMSE) values were obtained by comparing the polynomial estimations from RF and compressed US of muscle movement information with joint torque, acquired synchronously with US data using an isokinetic dynamometer. RESULTS: RF data provided a more accurate measurement of passive movement and active contraction, and was a greater predictor of net joint torque. The extra precision that the RF data provides was shown to be most reliable during passive length changes, with NRMSE significant (NRMSE > 0) in all cases. CONCLUSIONS: During passive joint rotations, the movements between consecutive US images present smooth and slow changes, conditions that are in many ways analogous to the ones observed in ultra-fast US imaging, which has frame rates greater than 1000 fps. This should be considered an important finding as it leads to believe that, as frame rates of standard US increase over time, the use of full resolution RF data will likely become imperative.

P3-K -69 Muscle material properties of stroke-impaired plantarflexor muscles

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BACKGROUND AND AIM: Impaired mobility is a common challenge for stroke survivors. In addition to decreased voluntary control, muscle properties may also be altered. In particular, muscle stiffness has important function implications as it influences force generation and transmission and range of motion. Our previous work showed that stiffness, measured as shear wave (SW) velocity using SW ultrasound elastography, is up to 59% greater in stroke-impaired biceps brachii muscle compared to the contralateral non-paretic muscle. To gain insight into changes in stiffness of lower extremity muscles, we measured SW velocity at different ankle angles to determine differences in the relationship between SW velocity and ankle positions between the paretic and non-paretic side of ankle plantarflexors (medial gastrocnemius, MG) and dorsiflexors (tibialis anterior, TA). METHODS: Fourteen stroke survivors participated in this study (age:60.15.9yrs; height:1.680.09m; body mass:77.612.5kg; time post-stroke:10.67.3yrs.). Subjects were seated with their knee in maximum extension and their foot secured to a platform of a dynamometer (System3Pro, Biodex). B-mode and SW elastography ultrasound measurements (Aixplorer, SuperSonic Imagine) of MG and TA muscles were captured, as well as joint angle, torque, and electromyography (Delsys) with the ankle at different angles (0 degrees dorsiflexion (DF), 15 degrees plantarflexion (PF), maximum DF, maximum PF, and two other intermediary angles that were torque-matched between the paretic and non-paretic side) while the muscle was passive. Quadratic fits were used to evaluate the relationship between SWS and ankle angle. Analysis of Variance was used to compare the SWV at the ankle angles of the non-paretic and paretic side. RESULTS: Our main findings show that SW velocity of the MG and TA increase non-linearly (quadratic fits of R^2: 0.940±0.05 and 0.820±19) from plantarflexion to dorsiflexion (muscle length). In addition to the SW velocity of the paretic MG muscle being on average 27.7% greater (p = 0.004) than the non-paretic side, the SW velocity was also significantly greater, on average 27.0% at 15 deg PF (p=0.0023), and 22.8% at the maximum DF (angle matched from paretic side, p=0.04). CONCLUSIONS: These results demonstrate that the passive stiffness across the range of motion and muscle lengths is greater in stroke-impaired muscle compared to the muscle of the non-paretic side of the MG, the primary plantarflexor muscle. This has possible implications for the affect of these changes in passive stiffness during gait. In addition to altered motor control and decreased muscle strength, having to overcome the increased stiffness at specific events during gait would certainly exacerbate any deficiencies. Having this information on muscle stiffness on a patient specific basis would allow clinicians to refine rehabilitation interventions and training to specifically address decreasing muscle stiffness.

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P3-K -70 Effects of rheumatoid arthritis in masticatory cycles of the women

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BACKGROUND and AIM: Mastication is one of the most important functions of the stomatognathic system and many factors can influence the masticatory performance, such as the loss of teeth, restorations in posterior teeth, bite force, age, gender, occlusal contacts, motor functional changes, orofacial pain, parafunctional habits and systemic alterations. The aim of this research was to analyze the efficiency of the masticatory cycles of the temporalis and masseter muscles, in women with rheumatoid arthritis, using the evaluation of habitual and non-habitual chewing. METHODS: 16 women with natural dentition (aged between 40 and 60 years) were divided into two groups: GI: rheumatoid arthritis (n=8, average age 51.50 ± 3.12 years) e GII: healthy control (n=8, average age 50.75 ± 3.18 years). The groups were matched subject to subject by age and body mass index. GI presented discomfort in the preauricular region, normal mandibular mobility, and absence of popping, clicking or grinding sounds in the temporomandibular joint. This study was previously approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo. The efficiency of the masticatory between individuals was evaluated by the ensemble average of the masticatory cycles (microvolts/second), during the time. The masticatory process was analyzed during habitual chewing of peanuts and raisins, and non-habitual chewing of flavorless gum (Parafilm M®; Pechinery Plastic Packaging, Batavia, IL, USA), for 20 seconds each. The values of ensemble average were normalized by the value of the EMG signal of maximum dental clenching (4s). Surface EMG was performed using TrignoTM Wireless EMG System Delsys. The EMG means were tabulated and subjected to statistical analysis using independent t test (SPSS 21.0). RESULTS: EMG activity was significant ($P < 0.05$) for chewing of Parafilm M® : RM= [(I = 0.66 ± 0, 09), (II=1.09 ± 0.13)] and chewing of peanuts: RM= [(I = 0.95 ± 0.05), (II=1.35 ± 0.13)]. CONCLUSION: The authors concluded that there was a decrease of EMG activity of the habitual and non-habitual chewing cycles of the masseter muscles in women with rheumatoid arthritis. ACKNOWLEDGEMENT: FAPESP and CNP

P3-K -71 Impact of complete implant-supported dentures anchored in the zygomatic bone in stomatognathic system

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AIM: The surgical treatments that use specific and different techniques as the zygomatic implant, which provides support for the dental prosthesis to rehabilitate edentulous arches with substantial amount of bone loss and no need for bone grafts. This research evaluated the electromyographic (EMG) activity of masseter and temporalis muscles in individuals with complete implant-supported dentures anchored in the zygomatic bone. METHODS: 54 volunteers of both genders, between the ages of 35 and 70 years (mean age 52.5 years) were selected for this study and distributed into two groups: ZIG (Zygomatic Implant, n=27) and CG (fully dentate subjects, n=27).The groups were matched subject to subject by age and body mass index. This study was previously approved by the Ethics Committee in Research of the School of Dentistry of Ribeirao Preto, University of São Paulo. Assessment of muscle activity was performed by EMG recordings of the right masseter (RM), left masseter (LM), right temporal (RT) and left temporal (LT) muscles, during protrusion (10s), right laterality (10s), left laterality (10s); dental clenching (4s) and maximal voluntary contraction on twice-folded parafilm sheet (Parafilm M®, Pechinery Plastic Packaging, Batavia, IL, USA) (18x17x4mm, 245 mg) and positioned between the occlusal surfaces of the superior and inferior first molars, bilaterally. Surface EMG was performed using Myosystem BR1 apparatus (Data Hominis Ltda., Uberlandia, MG, Brazil). The values were normalized by of the EMG signal of maximum dental clenching with Parafilm M® (4s). The EMG means were tabulated and subjected to statistical analysis using independent t test (SPSS 21.0). RESULTS: EMG activity was significant ($P \leq 0.05$) for protrusion: RM= [(ZIG = 0.44 ± 0.08), (CG=0.16 ± 0.02)], LM= [(ZIG = 0.49 ± 0.07), (CG=0.17 ± 0.02)], RT= [(ZIG = 0.21 ± 0.04), (CG=0.10 ± 0.01)], LT= [(ZIG = 0.17± 0.03), (CG=0.11 ± 0.01)]; right laterality: RM= [(ZIG = 0.32 ± 0.05), (CG=0.09 ± 0.01)], LM= [(ZIG = 0.39 ± 0.05), (CG=0.14 ± 0.02)], LT= [(ZIG = 0.17± 0.03), (CG=0.09 ± 0.01)]; left laterality: RM= [(ZIG = 0.44 ± 0.08), (CG=0.14 ± 0.03)], LM= [(ZIG = 0.28 ± 0.06), (CG=0.10 ± 0.01)], RT= [(ZIG = 0.16± 0.03), (CG=0.10 ± 0.01)]; dental clenching: LM= [(ZIG = 0.86 ± 0.05), (CG=0.68 ± 0.05)]; LT= [(ZIG = 0.93± 0.17), (CG=0.77 ± 0.04)]. CONCLUSION: Based on the analysis performed in the present research, it can be concluded that the oral rehabilitation with implant-supported prosthesis (anchorage in the zygomatic bone) promoted functional hyperactivity of the masseter and temporalis muscles when compared to the muscles of fully dentate individuals. ACKNOWLEDGEMENT: FAPESP and CNPq

P3-K -72 Fat infiltration of the Paretic Upper Limb in Individuals with Chronic Hemiparetic Stroke: Preliminary Results

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BACKGROUND AND AIM: The long-term effects of motor impairments on upper limb muscle architecture are unknown post stroke. It is hypothesized that motor impairments may cause decreased neural activation and subsequent decreased use of the paretic limb, which over time may cause muscle atrophy and fatty infiltration. The aim of this research is to quantify long-term changes in intramuscular, perimuscular and subcutaneous fat following hemiparetic stroke. METHODS: Magnetic resonance images were acquired from 5 stroke subjects using a 3D gradient echo pulse sequence of the upper limb (TR=7ms, flip angle=12°, matrix size = 256x216, slice thickness = 3mm). The Dixon method was used to estimate percent fat using an echotime (TE) of 2.39ms, when water and fat are in phase and a TE of 4.77ms, when water and fat are out of phase. Percent fat was calculated using a ratio of the intensity of the fat image compared to the intensity of the water image. Using AnalyzeDirect, manual segmentation of the biceps, triceps, brachialis and coracobrachialis was done to measure intramuscular fat and of the upper limb muscle compartment as a whole to measure perimuscular fat. Manual segmentation of the subcutaneous fat compartment from the superior aspect of the axilla to the olecranon process was done to measure the volume of subcutaneous fat. RESULTS: The average percent fat for the upper limb muscle compartment as a whole was 16.30% for the paretic limb and 9.23% for the non-paretic limb. The average percent intramuscular fat was 7.25% for the muscles in the non-paretic limb and 10.77% for the muscles in the paretic limb. The percent intramuscular fat of the paretic biceps was 3.25% greater than the non-paretic biceps, 2.60% for the triceps, 4.3% for the brachialis and 3.93% for the coracobrachialis. The volume of subcutaneous fat was 11.21% greater in the paretic upper limb compared to the non-paretic upper limb. CONCLUSIONS: The percent intramuscular fat was greater in the paretic limb compared to the non-paretic limb for the biceps, brachialis, triceps and coracobrachialis muscles. The percent fat for the muscle compartment as a whole was greater in the paretic upper limb compared to the non-paretic, suggesting an increase in perimuscular fat. The volume of subcutaneous fat was greater in the paretic upper limb compared to the non-paretic upper limb. Deficits post stroke, especially musculoskeletal changes like muscle fat infiltration and atrophy, are not fully understood. Rehabilitation of the upper limb post stroke varies widely and outcomes are variable. Further information about musculoskeletal changes post stroke may help guide rehabilitation towards more efficacious treatments.

P3-K -73 Greater fatigability among type 2 diabetics without neuropathy is not associated with disruption of neuromuscular propagation or corticomotor excitability

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Background and Aim We have demonstrated that people with type 2 diabetes (T2D) exhibit greater reductions in muscle force and power (i.e. greater fatigability) than non-diabetic controls, after a dynamic fatiguing contraction. Furthermore, people with T2D and diabetic polyneuropathy (DPN) have greater fatigability compared with controls and this is associated with impaired neuromuscular propagation (decreased amplitude of compound muscle action potential, M wave) (Allen, MD et al 2015 JAP). However, it is unknown if disruption of neuromuscular propagation contributes to greater fatigability among patients with T2D who have no symptoms of DPN. The purpose of this study, therefore, was to determine if greater fatigability among people with T2D and no DPN was associated with impairments of neuromuscular propagation. A secondary aim was to determine if corticomotor excitability (assessed with motor evoked potentials (MEPs)) is impaired among T2D. Methods 16 people with T2D (9 men, 7 women; 58.6±8 years) and 17 age-, activity-,and BMI-matched controls without diabetes (10 men, 7 women; 58.7±10 years) performed a 6-minute single-limb dynamic protocol through 90° of knee extension while seated at 90° of hip and knee flexion. 120 maximal velocity concentric contractions (MVCC) were performed (1 per 3 s) with a load equivalent to 20% maximal voluntary isometric contraction (MVIC) torque. MVICs were performed before and immediately after the fatigue protocol. EMG from the vastus lateralis, vastus medialis, and rectus femoris were collected using bipolar electrodes, sampling at 2,000 Hz, band-pass filtered (13 - 1,000 Hz) and amplified (100×). Before and after the dynamic fatiguing contraction, M waves were elicited at rest with supramaximal femoral nerve stimulation and MEPs were evoked with transcranial magnetic stimulation over the motor cortex during maximal and submaximal isometric contractions. The properties of these EMG responses were assessed (amplitude, area, and latency of the MEPs and M waves) in order to quantify corticomotor excitability and neuromuscular propagation. Results People with T2D demonstrated greater reductions in MVCC power (38.4±5% vs. 23.5±16%; time × group, $p < 0.05$) and MVIC torque (42.9±19% vs. 32.7±9%; time × group, $p < 0.05$) compared with controls. T2D and controls both demonstrated reductions in the MEP and M wave amplitudes and areas (time, $p < 0.05$); and increased latency of the MEP and M wave (time, $p < 0.05$); and no group differences were evident (time × group, $p > 0.05$). Conclusions People with T2D and no clinical signs or symptoms of DPN demonstrated greater fatigability compared with controls after a dynamic fatiguing contraction, however, the greater fatigability among T2D was not due to disruption of corticomotor excitability or neuromuscular propagation. Among patients with T2D and no DPN, corticomotor excitability and neuromuscular junction propagation likely do not contribute to increased fatigability.

P3-K -74 Intra-rater reliability and agreement in the ankle electromyography activity emg during sit to stand in healthy young adults

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BACKGROUND AND AIM: EMG is a neurophysiologic measurement of the muscle electrical activity, used for assessment of the activation and recruitment pattern. In functional activities, such as Sit to Stand (STS),EMG pattern of the lower limb has been evaluated, specifically activity of the Tibialis Anterior(TA), Soleus(SO),Medial Gastrocnemius(MG) and Lateral Gastrocnemius(LG),since these muscles play important role for foot stability, displacement the center of gravity and anticipatory movements. It has been reported a EMG reliability moderate to excellent (Intraclass Correlation Coefficient ICC:0.57-0.92) during isolated muscle contractions of trunk and knee(isometric, concentric or eccentric), however there is not available information regarding the STS task. The aim is to evaluate the intra-rater reliability and the agreement level of the ankle muscles EMG analysis during STS.METHODS:An evaluation of a diagnostic test, with a non-probability sampling. Participants performed three STS trials and the average was used for statistical analysis. TA, SO, MG and LG were assessed synchronizing EMG surface signal (sEMG) with a load cell to differentiate stages of pre-extension (start of movement to takeoff) and extension (takeoff to stand). The sEMG was normalized by submaximal voluntary contraction (SVC) and signal processing was performed using specific routines in MATLAB. The variables were: Root Mean Square (RMS); amplitude; and Median Frequency (MF). In order to enhance the independence of the measurements, the same rater conducted the two assessments with a period of eight days between them. Reliability was analyzed by the ICC and agreement with the Bland-Altman method.RESULTS:Ten healthy participants of both genders aged 24.3±1.6 years, height 165.6±9.4 cm and weight 63.1±13.1 kg were included in the study. The reliability for the RMS amplitude was good to excellent in the pre-extension:TA(ICC:0.70),LG(ICC:0.92),SO(ICC:0.91), and the extension: TA(ICC:0.84), LG(ICC:0,94) and SO(ICC:0.92). Same results were observed for the FM in pre-extension: TA(ICC:0.88), LG(ICC:0.64) and SO(ICC:0.81). For MG, the reliability was acceptable for the RMS amplitude in pre-extension (ICC:0.32), extension (ICC:0.36); and FM in pre-extension (ICC:0.45), but FM in extension was moderated (ICC:0.60). The Bland-Altman method showed mean differences of the measures close to zero and narrow limits, except the FM of the GM in both phases, pre-extension: 4,92(95% limits of agreement -43.3, 53.1) and extension: 0,54(-39.9, 41.1).CONCLUSIONS:In this population, the measurement is reliable when it is performed with a standardized and synchronized technique during functional task. Therefore, it is recommended in future studies to evaluate the psychometrics properties of these test in people with impaired movement to determine the muscle electrical activity and the effect of therapeutic interventions, without the changes been attributed to error or measurement variability.

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P3-K -75 Ageing and electromyographic fatigue patterns of masticatory muscles

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BACKGROUND AND AIM: Muscle fatigue is induced during a constant force isometric contraction, determining the functional performance and the resistance of the individual. The purpose of this research was to determine electromyographic (EMG) fatigue, by median frequency (MF) of the EMG signals of masseter and temporalis muscles in children, adolescents, adults and elderly to demonstrate the normal parameters of the masticatory muscles based on age. METHODS: 74 volunteers (age 7-80 years), fully dentate (except for I - mixed dentition) were divided into five groups: I (7-12 years), II (13-20 years), III (21-40 years), IV (41-60 years) and V (61-80 years). All groups were divided with respect to gender (08M / 08F), except for Group V (05M / 05F). This research was approved by the Ethics Committee in Research of the School of Dentistry of Ribeirão Preto, University of São Paulo. The EMG analysis was performed using the Myosystem-Br1 apparatus. The analyses of the median frequency data EMG signal were standardized obtaining the values of the select windows of 5 seconds length duration at initial time (IMF), medium time (MMF) and final time (FMF) of total length duration of each analysis. EMG fatigue was obtained during a constant force isometric contraction .The total length (seconds) for EMG fatigue of the groups were: I (29.12 ± 4.88), II (32.16 ± 3.28), III (39.57 ±3.50), IV (41.68 ±4.74) and V (60.97 ± 9.82). Normalized median frequency were tabulated and subjected to statistical analysis (ANOVA; SPSS 21.0). RESULTS: There were no statistically significant differences ($P < 0.05$) between the Groups for the median frequency (Hz) of the EMG signals of masseter and temporalis muscles: Right Masseter: IMF=[(I=1.01 ± 0.03, II=1.03 ± 0.03, III=0,94 ± 0.02, IV=0.95 ± 0.02, V=0.92 ± 0.05)], MMF=[(I=0.93 ± 0.02, II=0.89 ± 0.04, III=0.86 ± 0.04, IV=0.87 ± 0.02, V=0.86 ± 0.05)], FMF=[(I=0.92 ± 0.03, II=0.80 ± 0.05, III=0.83 ± 0.05, IV=0.78 ± 0.04, V=0.80 ± 0.05)]; Left Masseter: IMF=[(I=1.01 ± 0.03, II=1.03 ± 0.05, III=0.93± 0.03, IV=0.98 ± 0.03, V=0.97 ± 0.01)], MMF=[(I=0.90 ± 0.03, II=0.91 ± 0.05, III=0.85 ± 0.04, IV=0.91 ± 0.03, V= 0.92 ± 0.02)], FMF=[(I=0.91 ± 0.03, II=0.84 ± 0.05, III=0.81 ±0.04, IV=0.84 ± 0.03, V=0.90 ±0.04)]; Right Temporal: IMF=[(I=0.98± 0.02, II=1.00 ± 0.03, III = 0.97 ± 0.01, IV = 0.94 ± 0.01, V = 0.99 ±0.01)], MMF=[(I =0.91 ± 0.03, II=0.89 ± 0.04, III=0.89 ± 0.03, IV=0.89 ± 0.01, V=0.93 ± 0.04)], FMF=[(I=0.87 ± 0.04, II=0.83 ± 0.04, III= 0.82 ± 0.04, IV=0.84 ±0.02, V=0.88 ± 0.05)]; Left Temporal: IMF=[(I= 0.97 ± 0.03, II=1.04 ± 0.03, III = 0.96 ± 0.02, IV=0.98 ± 0.02, V=0.98 ± 0.03)], MMF=[(I=0.90 ± 0.03, II=0.92 ± 0.03, III=0.88 ± 0.03, IV=0.91 ± 0.02, V=0.91 ± 0.03)], FMF=[(I=0.88 ± 0.04, II=0.87 ± 0.03, III=0.79 ± 0.04, IV=0.85 ± 0.02, V=0.88 ±0.02)]. CONCLUSION: The results this research showed that age is not

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associated with EMG fatigue of masseter and temporalis muscles. ACKNOWLEDGEMENT: FAPESP