XVI CONGRESS
OF THE INTERNATIONAL SOCIETY OF ELECTROPHYSIOLOGY AND KINESIOLOGY

Lingotto Conference Centre

Torino, Italy June 28-July 1, 2006

PROCEEDINGS

FROM RESEARCH TO PRACTICE

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WELLCOME OF THE ISEK PRESIDENT

As president of the International Society of Electrophysiology and Kinesiology (ISEK) let me welcome you all to join the XVI congress of ISEK being held in Torino, Italy.

The congress will provide a comprehensive scientific program covering the most recent advances in Electrophysiology, Electromyography and Kinesiology and I noticed with pleasure that a great number of contributions have been submitted to this congress. The ISEK 2006 will give the opportunity to engineers, physiologists, medical and rehabilitation doctors as well as physical therapists to exchange their experience and to discuss the most recent advances in this exciting and steadily growing field. It is the scientific association that really brings together the different disciplines in order to bridge from research to practice. This is the basis for a creative atmosphere which will - as we all know - give rise to new bright and creative ideas and approaches.

Let me especially welcome the many young investigators presenting their work. Science transport through education and training means transporting science to the next generation. I invite you to join the scientific community of ISEK and I hope that the congress will be able to motivate you to continue your work with lots of zest.

I would like to thank Roberto Merletti - the secretary general of ISEK 2006 - and his team for the excellent work they have done up to now. I am sure that this congress will be very productive scientifically, professionally and socially. Enjoy the scientific program which looks promising and I wish you a lot of success but also a lot of fun. I hope that everyone has the opportunity to encounter old friends and make new friendships and, last but not least, the time to visit the beautiful city of Torino.

ISEK President
Catherine Disselhorst-Klug
Helmholtz-Institute, Aachen, Germany

WELLCOME TO PARTICIPANTS

After Pavia (1976) and Florence (1992) Torino is the third Italian city to host the ISEK Congress.
Torino is known for its tradition of hard work performed well and unassumingly and, although it does not have the art appeal and glamour of Venice or Florence, its charm has attracted the world's attention with the recent Olympic Winter Games. Its Schools of Medicine and Engineering are well known since the times of J. L. Lagrange (Giuseppe Ludovico Lagrangia) and A. Mosso and because of three Nobel Price winners educated here.
Although mechanical, electronics and computer engineering have been the hard core of research activities in the Torino area in the last ten years, interdisciplinary research in the biomedical engineering field has grown and has achieved international recognition, in particular in the field of the neuromuscular system.
The selection of Torino as the city hosting the XVI ISEK Congress recognises this development and makes Italian researchers in this field very proud and honoured. The Laboratory for Engineering of the Neuromuscular System and motor rehabilitation (LISiN) of Politecnico of Torino has accepted the task of organizing the Congress with the financial contributions of the Institutions mentioned in this book and the supervision of the ISEK Council. The Invited Lecturers, Workshop Organizers, and Track Chairs have substantially contributed to this endeavour and to the scientific level of the event, together with Carla Vaschetto, and Dr. Marco A. Minetto who contributed to its organization.
As all previous ISEK Congresses, this edition is an opportunity for presentation, exchange, dissemination of results and transfer of knowledge from the academic laboratories to the clinical community and to the industrial world. This transfer is an important but not easy task and for this reason the Congress' motto is "From research to practice". The increasing participation of clinicians to applied research and the decreasing attractiveness of canned tools and packages to be used blindly, without understanding of their limitations and capabilities, are signs as positive as the increasing social and economic awareness for ergonomics, occupational, rehabilitation and elderly medicine. ISEK can bring a major contribution in these fields as well as to basic research in physiology.
We welcome and thank all participants to the XVI ISEK Congress and we strongly believe that our efforts will be more than rewarded if we will succeed in eliciting in students a sense of marvel and curiosity towards electrophysiology and kinesiology and in attracting new motivated researchers in these interdisciplinary fields whose impact in society and economics is rapidly growing.
We will all return home with new knowledge and ideas, with a new experience of learning from each other, and new things to teach and transfer to others. We are grateful to all of you for contributing to this. May these feelings accompany us and the new generations in the years to come, in the tradition initiated by Prof J. Basmajian.
We will do our best to make you stay in Torino pleasant and fruitful.
Thank you for participating to the XVI ISEK Congress.

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Awards

CRT Foundation Award for clinical application

Compagnia di San Paolo Foundation Award for basic research

DelSys recognition for Best EMG Presentation

John V. Basmajian Student Investigator Award

SME (Small Medium Enterprise) Award for technology transfer

WELLCOME COCKTAIL

Ciak Bar – Mole Antonelliana

The National Museum of the Cinema is one of the richest and most exciting exhibitions of cinema. The museum is located in the historical centre of Turin, inside the Mole Antonelliana. A panoramic lift runs up through the centre of the building carrying visitors to the 'terrace', which offers a spectacular showing of the exposition areas and the panorama of the city from above.
Unique objects are exhibited from the period of silent films: from Charlie Chaplin's bowler hat to Rudolph Valentino's costume in Sangue e Arena. There are also objects from sound films like the James Cameron's Aliens, the head of most disturbing predator ever to appear on the screen, Jaws, by Steven Spielberg and even Darth Vader's helmet from The Empire Strikes Back by Irvin Kershner.
Thanks to its rich collections and documentary material, The National Museum of the Cinema has became a leading, avant-garde museum of international importance. At this time, The Museum of the Cinema has 12,000 film prints in its film library, 9,000 objects of art, paintings, old prints, apparatus for viewing and filming, 741,000 photographic documents, 342,000 posters, a library (26,000 volumes and 3,400 periodical titles) sound and paper archives of great historical value. Considered amongst the most important internationally, the collections contains above all, objects which date back to before the birth of the cinema and silent films, largely collected by Maria Adriana Prolo, a great fan of cinema and founder of the Museum.

The National Museum of the Cinema
Fondazione Maria Adriana Prolo
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10124 Torino, Italy
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www.museocinema.it

GALA DINNER

The Turin Automotive Museum
"CARLO BISCARETTI DI RUFFIA" of Torino

The Turin Automotive Museum is one of the largest in the world and the only one of its kind in Italy. It forms one of the city's leading national and international attractions.
Carlo Biscaretti di Ruffia was a man of many parts: journalist, painter, humorist, designer, model-maker and above all a car-lover with an interest in the history and development of the automobile. From 1932 onwards, he built up the impressive collection of vehicles, memorabilia and records of great historical value that still forms the core of the museum's exhibits. He was the museum's first president and it took his name on his death in 1959.
The museum's present premises were inaugurated in 1960. Disegned by A. Albertini is still regarded as one of modern Turin's most architecturally interesting buildings.
A collection of 170 cars offers the visitor an enthralling panorama of the history of the motor-car and its engines from the earliest days down to our own times. The arrangement is by chronological periods. The collection comprises many unique or very rare items: Bordino's steam-driven landau (1854), the Itala that won the Pekin to Paris race in 1907 and the one that belonged to Queen Margherita of Savoy (1909), the revolutionary Ford T (1916) of which more than 15 million were sold in twenty years, a Rolls Royce "Silver Ghost" (1914), an Alfa Romeo 1750 (1929), and prestigious Isotta Fraschini, including the one used by Gloria Swanson in the film "Sunset Boulevard" (1929). The sports and racing cars include Antonio Ascari's and Farina's Alfa Romeos, Fangio's Maserati and Mercedes, the Formula 1 Ferraris used by Ascari, Surtees, Gilles Villeneuve and a wonderful Lancia D50 (1955) and many others.
The museum is also the home of a modern Congress Centre with an Auditorium capable of seating 400 persons, a room capable of seating 80 persons and other rooms smaller, as well as a 800 square-metre Foyer.
The museum's Documentation Centre boasts a library with more than 6000 volumes, 180 series of reviews, journals, etc., tens of thousands of papers, photographs, catalogues, drawings and other documents, an extensive filing system and a reading room.

The Turin Automotive Museum
"CARLO BISCARETTI DI RUFFIA"
Corso Unità d'Italia, 40
10126 Torino
www.museoauto.it

Social Events

SIX PRE-CONGRESS WORKSHOPS/ WEDNESDAY, JUNE 28, 2006, BUSINESS CENTER, 2ND FLOOR (14.30 - 18.30)

Pre-Congress Workshops

W1 *Sala C. Disselhorst-Klug*

RESPIRATORY MUSCLES: AN INTERESTING APPROACH TO PULMONARY DISEASES

Organizers:
E. N. Bruce, Center for Biomedical Engineering University of Kentucky (USA)
M. A. Mañanas, Biomedical Eng. Research Center, Technical University of Catalunya, Barcelona, Spain

W2 *Sala S. Roy*

EMG AND EXERCISE PHYSIOLOGY

Organizers:
M.A. Minetto, Dipartimento di Medicina Interna, Università di Torino, Italy
A. Rainoldi, Laboratorio di Ingegneria del Sistema Neuromuscolare, Politecnico di Torino, Torino, Italy and SUISM, Università di Torino, Torino, Italy

W3 *Sala H. Hermens*

WEARABLE/AMBULATORY TECHNOLOGY AND ITS APPLICATIONS

Organizers:
P. Bonato, Movement analysis Laboratory, Harvard University, Boston, USA
D. De Rossi, PhD, Center "E. Piaggio", University of Pisa, Pisa, Italy

W4 *Sala C. J. De Luca*

INSIGHTS INTO THE CONTROL OF MOTOR UNITS

Organizers:
C. J. De Luca, NeuroMuscular Research Center, Boston, USA
A. Adam, NeuroMuscular Research Center, Boston, USA

W5 *Sala M. Solomonow*

INTERPRETATION OF THE SURFACE EMG

Organizers:
R. Enoka, University of Colorado, Boulder CO, USA
D. Farina, Center for Sensory-Motor Interactions, University of Aalborg, Aalborg, DK

W6 *Sala A. Sherwood*

SENSORY-MOTOR INTERACTION AND MUSCLE PAIN

Organizer:
T. Graven-Nielsen, Center for Sensory Motor Interaction, University of Aalborg, Aalborg, DK

W1. *Sala C. Disselhorst-Klug*
RESPIRATORY MUSCLES

Respiratory muscles provide the mechanical energy that supports breathing. Evaluation of their control and performance in relation to temporal activities and fatigue can provide insights into respiratory pathologies such as chronic obstructive pulmonary disease, obstructive sleep apnea syndrome where the upper airway muscles are directly involved, or neuromuscular compensations for lung disease. In spite of the fact that respiratory muscles have been studied extensively during the last forty years, it is still an open question whether new approaches can be applied in different applications such as diagnosis of pulmonary disease, training of muscles to enhance exercise performance, or monitoring of mechanical ventilated patients, and in other situations where these muscles are specially important.

A brief introduction to the anatomy and function of respiratory muscles will be provided. Experts in the field will present various methods for the analysis of muscle function: surface and transcutaneous electromyographic recordings, mechanomyographic signals, and imaging techniques such as tomography and MRI. In addition, electrical stimulation techniques will be discussed. Finally, recent nonlinear techniques will be applied to myographic signals in order to evaluate couplings and interactions in respiratory muscle activities under different ventilatory conditions. The Workshop will finish with an Open Discussion of important research directions.

SPEAKERS

Metin Akay
Harrington Department of Bioengineering. Fulton School of Engineering. Arizona State University, Tempe, Arizona, USA

Eugene N. Bruce
Respiratory Dynamics Laboratory. Center for Biomedical Engineering, University of Kentucky, Lexington, Kentucky, USA

Miquel Angel Mañanas
Dept of Automatic Control and Systems Engineering. Biomedical Engineering Research Center, Technical University of Catalonia, UPC, Barcelona, Spain

Wim M.C. van Aalderen
Subdivision of Pediatric Respiratory Medicine. Emma Children's Hospital, University Hospital, Amsterdam, The Netherlands

PROGRAM

Miquel Angel Mañanas and Eugene Bruce: Introduction and overview of the workshop

Eugene Bruce: Coordination of respiratory muscles by neural and chemoreflex mechanisms

Wim M.C. van Aalderen: Assessment of respiratory disease using respiratory muscle EMGs

Miquel Angel Mañanas: Respiratory muscle activities at different levels of ventilatory effort in health and disease

Metin Akay: Respiratory Related Evoked Responses in Obstructive Sleep Apnea Subjects

Open Discussion of new research directions

Eugene N. Bruce, Ph.D.
Respiratory Dynamics Laboratory, Center for Biomedical Engineering,
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W2. *Sala S. Roy*
EMG AND EXERCISE PHYSIOLOGY

In recent years, in the field of Exercise and Sports, where intense efforts to achieve excellence and increase competitiveness are always required, technology applied to the study of skeletal muscles became an important mean to increase comprehension of the movement dynamics and to assess the effectiveness of training procedures.
Muscles are known to be made up of motor units consisting of two main fiber types with different metabolism, mechanical and electrophysiological properties. Type II fibers appear to have larger diameters with higher conduction velocity (CV) and faster decrement of CV during sustained contractions. Fiber composition is usually investigated by biopsy and histochemical analysis. Many researchers have investigated the relationship between EMG signal and fiber constituency in the attempt to identify a non-invasive procedure to estimate fiber distribution in a given muscle. If the findings from animal studies will be demonstrated to be applicable to humans, this possibility would be very relevant in sports medicine.
During voluntary and/or electrically elicited isometric contractions, the electrophysiological properties of muscle fiber membrane determine changes (preceding mechanical fatigue) in the EMG signal that are called "myoelectric manifestations of fatigue". For these reasons, surface EMG is suggested as an effective techniques in detecting muscle activation pattern, motor unit recruitment at different contraction intensities, and the early changes occurring within muscle which is damaged by acute exercise.
There has been also a tendency to extrapolate these findings to dynamic contractions. In these cases the situation is more complicated by, a) the fact that EMG signal is non stationary and traditional spectral analysis must be used with caution, b) relative movement between electrodes and muscle may create artefacts, and c) the active motor unit pool may change during movement.
Few works in the literature evaluated the effect of the training on the characteristics of the neuromuscular system in term of peripheral or central control adaptations. The most promising approaches seem to include the combined assessment of mechanical and myoelectric manifestations of fatigue with biological markers (lactate, autocrine, and paracrine factors produced by skeletal myocytes) during repeated sessions of strenuous exercise.
The aim of the workshop is to discuss, from the above-mentioned points of view, the usefulness of surface EMG in the characterization of muscular responses to both the acute and chronic exercise.

PROGRAM

Mechanical and myoelectric properties and fiber type composition of muscles
B.Gerdle, MD, PhD

EMG and MMG evaluation of neuromuscular responses to acute exercise
T.Moritani, PhD

Neuromuscular adaptations during prolonged strength training and detraining
M.Narici, PhD

Surface EMG recordings during dynamic muscle contractions
A.Rainoldi, PhD

Biochemical responses to exercise and their relationship with myoelectric manifestations of fatigue
M.A. Minetto, MD

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W3. *Sala H. Hermens*
WEARABLE/AMBULATORY TECHNOLOGY AND ITS APPLICATIONS

The objective of the workshop is to provide an overview of recent advances in wearable technology and to discuss its numerous emerging clinical applications. The program will be opened with two lectures on textile and wireless technology respectively. These are technologies that have made it possible to develop unobtrusive systems to monitor motor activities and associated systemic responses over extended periods of time. The following lectures will present a variety of applications of wearable technology that will allow attendees to appreciate the significant impact that wearable systems are currently having on research and clinical practice. Methodological matters concerning the reliability of the data gathered via wearable sensors and of the analyses performed to assess motor status and measure systemic responses will be addressed. Applications demonstrated in the workshop will include mobility assessment, evaluation of motor disorders, titration of medication intake, optimization of exercise conditions, and optimization of exercise.

PROGRAM

Designing Smart Textile Garments for Long-Term Monitoring of Patients' Status
Danilo De Rossi, PhD

Human++: Technology for Wireless Body Area Networks
Bert Gyselinckx, PhD

A Smart Textile T-Shirt for Long Term Monitoring of ECG and EMG Signals
Leif Sandsjö, PhD

Using Wearable Technology to Enable Remote Monitoring and Remotely Supervised Training in Rehabilitation
Hermie Hermens, PhD

Theoretical Concepts, Practical Experiences and Results from a Decade of Vocational Recordings to Understand Shoulder-Neck Pain
Rolf Westgard, PhD

Enhancing Balance via Wearable Biofeedback Systems
Laura Rocchi, PhD

A Wearable Unit to Optimally Adjust Workload During Exercise Sessions
Tohru Kiryu, PhD

The Wearable Revolution in Physical Medicine and Rehabilitation
Paolo Bonato, PhD

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Department of Physical Medicine and Rehabilitation, Harvard Medical School
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W4. *Sala C. J. De Luca*
INSIGHTS INTO THE CONTROL OF MOTOR UNITS

TECHNOLOGY

The Importance of Accurate Measurements - For the past three decades we have been improving a technique that we have called Precision Decomposition, which has provided us with an accurate view of the firings of concurrently active motor units. The technique, which consists of specialized sensors, a data acquisition unit, and signal decomposition algorithms, has been useful for decomposing intramuscular EMG (iEMG) signals during isometric contractions and has been used in numerous physiological studies. The latest version typically yields 10 motor unit action potential trains with an accuracy of typically 85% with a processing time of only 8 times the acquisition time. Through the use of an interactive editor program decomposition accuracies of 100% can be obtained in some records of EMG signals.

FINDINGS

Common Drive phenomenon - The firing rates of motor units fluctuate in unison with essentially no time delay between them, as demonstrated by a lack of phase shift in the cross-correlation functions of the firing rates. This indicates that a common source acts on the motoneuron pool of all the motor units within a muscle and to a lesser, but significant extent, on its synergists and antagonists.

Onion Skin phenomenon - During isometric contractions earlier recruited motor units almost always (with only rare exceptions) fire at greater average rates than later recruited motor units. (When plotted, the firing rates form overlapping layers resembling the structure of the skin of an onion.) Our iEMG technology established the onion skin concept because we were able to study several motor units during individual contractions. This finding ran counter to the previously held belief that higher threshold motor units would be expected to fire faster to fuse and produce more force. By firing at lower firing rates, the high threshold, fast fatiguing motor units are able to remain active for longer periods of time. Motor unit control regulates the combination of contraction force and contraction time rather than only the contraction force. The existence of the onion skin and the common drive also imply that the hierarchal firing rate behavior is a property of the architecture of the motoneuron pool.

Muscle Size and Motor Unit Control - The motor units of relatively small muscles innervated by the cranial and cervical nerves (e.g., First Dorsal Interosseous, Adductor Pollicis, and Orbicularis Occuli) tend to be recruited in the force range up to 50% of the maximum voluntary contraction (MVC), have mean firing rates which reach relatively high maximum values (approx. 40 pulses per second, pps), and have a considerable disparity in the firing rate values. Whereas, those in larger muscles, such as the Trapezius, Biceps Brachialis, Tibialis Anterior, Vastus Lateralis and Vastus Medialis are recruited in a force range up to 80% MVC, have firing rates which reach relatively lower maximum values (approx. 25 pps), and have less disparity in the firing rate values.

Motor Unit Substitution - While studying long-duration contractions in the range of 10 min, we found that motor units in the Trapezius muscle stopped firing when the contraction activity level decreased slightly, and in response to a subsequent slight increase in the force output a new motor unit was recruited in place of the one which was de-recruited. This observation provided evidence for a long-held, but never previously shown, belief that motor unit substitution of motor units can take place during very specific circumstances in long duration contractions.

Fatigue - Studies of the behavior of individual motor units during contractions to exhaustion indicate that the rules governing motor unit firing behavior remain unchanged during the progression of fatigue. Any changes in the mechanical properties of the muscle are complemented in reverse by changes in the recruitment and firing rates of motor units. It appears that the CNS regulates the excitatory drive to compensate for the loss of force generated by the fibers, but the relationship between firing rate and recruitment remains unaltered.

Age and Motor Unit Control - Studies of the common drive in the elderly revealed that in approximately one-half of the investigated subjects the firing rate cross-correlation between pairs of motor units in a hand muscle was severely reduced and in some instances appeared non existent. Also, the onion skin phenomenon was disrupted; pointing to neurological alterations in the CNS as a function of aging. Elderly individuals generate lower firing rates to produce equivalent MVC than younger individuals. This is consistent with separate observations that the force twitch of motor units is altered as a function of age.

Handedness and Motor Unit Control - In humans who show a clear preference for one hand we observed lower average firing rates, lower recruitment thresholds, and greater firing rate/force delay in the dominant hand. These results are consistent with the notion of an increased percentage of slow twitch fibers in the preferentially used muscle, allowing twitch fusion and force buildup to occur at lower firing rates. Thus, a lifetime of preferred use may have caused adaptations in the fiber composition of the dominant muscle such that the mechanical effectiveness of its motor units increased.

Microgravity and Motor Unit Control - Understanding the neuromuscular basis for microgravity-induced degradation in motor function is essential for the educated design of programs to counter the effects of microgravity. We have begun studying the firing activity of motor units in astronauts before and immediately following short-duration (13 days) Space Shuttle missions, as well as during the course of recovery after re-exposure to Earth gravity.

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W5. *Sala M. Solomonow*
INTERPRETATION OF THE SURFACE EMG

The information extracted from the surface electromyographic (EMG) signal typically provides a global measure of motor unit activity, due to the inability of the traditional 2-electrode recording to detect activity at the level of single motor units. Global EMG characteristics, such as amplitude and spectral features, are used to determine the underlying physiology with an inverse modeling approach that models the association between EMG and physiological variables at various degrees of complexity. Such models enable an investigator to isolate the underlying physiology responsible for an observed EMG signal. For example, changes in average muscle fiber conduction velocity can be estimated by modeling the effect of conduction velocity on power spectrum as a scaling factor. This approach, however, requires simplifications to reduce the number of parameters and multiple solutions that influence the association between measured variables and the physiology.
The aim of this workshop is to discuss the interpretation of the surface EMG by emphasizing both the type of information that can be reliably extracted from the signal and the limitations in the use of this technique. A mathematical modeling approach allows the characterization of the sensitivity of the surface EMG to the parameters of the systems involved in the generation and detection of the signal. The workshop comprises an overview of modeling approaches (Dick Stegeman), description of techniques for information extraction from the surface EMG (Dario Farina), and limits in the interpretation of the signal when using these techniques to assess the neural strategies associated with various movements (Kevin Keenan, Madeleine Lowery, Luca Mesin).

PROGRAM
Introduction (R. Enoka)
Surface EMG modeling - An overview (D. Stegeman)
Information extracted from the surface EMG (D. Farina)
Limitations of the surface EMG for the extraction of neural strategies (K. Keenan)
Advanced motor unit models and their use in the interpretation of the surface EMG (M. Lowery)
Advanced volume conductor models and their use in the interpretation of the surface EMG (L. Mesin)
Open discussion

Roger M. Enoka
Department of Integrative Physiology
University of Colorado in Boulder, USA

Dario Farina
Center for Sensory-Motor Interaction (SMI),
Faculty of Engineering and Science,
Department of Health Science and Technology
University of Aalborg, Aalborg, Denmark

W6. *Sala A. Sherwood*
SENSORY-MOTOR INTERACTION AND MUSCLE PAIN

Musculoskeletal pain is a key health issue affecting a majority of people. An important direction for research and clinical practice is to improve the management of these conditions. This workshop will focus on how deep-tissue pain interacts with the motor control system and how this interaction depends on the specific motor task (rest, static, and dynamic contractions).
Experimental pain research is a way to investigate the basic motor control mechanisms affected by muscle pain; pain is induced in a standardised way and the responses (e.g. motor control changes) are assessed quantitatively in standardised conditions. One important advantage with experimental muscle pain studies is that the cause-effect relationship is known, i.e., the effects of pain on movement co-ordination can be described. The mutual link between experimental muscle pain and changes in motor control cannot be directly transferred to the clinical conditions with chronic muscle pain. Nevertheless, several clinical examples of chronic muscle pain will be presented (e.g. low back pain and neck-shoulder pain) demonstrating similar changes in the muscle co-ordination as found with experimental muscle pain.
The interactions between muscle pain and motor control depend on the specific motor task. In general, muscle pain causes no increase in muscle activity at rest and reduces maximal voluntary contraction and endurance time during submaximal contractions. Moreover, muscle pain causes a change in co-ordination during dynamic exercises. The contemporary view is that pain affects movement according to the "pain-adaptation" model that proposes that activity of agonist (force-producing) muscles is reduced, whereas that of the antagonist (counter-acting and controlling) muscle is increased; i.e. a decrease in movement amplitude and velocity due to muscle pain.
The functional adaptation to muscle pain may also involve increased muscle activity reflecting changed muscle co-ordination and strategy. This workshop will present an update on the interaction between muscle pain and the motor control based on clinical and experimental studies utilising various techniques based on electromyography (array and matrix surface, fine-wire) and mechanomyography.

Topics:
- Experimental muscle pain and motor control (Thomas Graven-Nielsen, PhD)
- The sensory-motor control involved in low back pain (Paul Hodges, PhD)
- Electromyography and mechanomyography in work-related pain conditions (Pascal Madeleine, PhD)
- Muscle deficits in neck pain disorders (Deborah Falla, PhD)

Thomas Graven-Nielsen, PhD, Assoc. Prof.
Laboratory for Experimental Pain Research
Center for Sensory-Motor Interaction (SMI)
University of Aalborg, Aalborg, Denmark

Invited Lectures

BASMAJIAN LECTURE / THURSDAY, JUNE 29, 2006, SALA 500 (h. 09.30-10.30)

Prof. Phil Parker, PhD, University of New Brunswick, Canada

Philip A. Parker received the B.Sc. degree in electrical engineering from the University of New Brunswick (UNB) in 1964, the M.Sc. degree from the University of St. Andrews (Scot.) in 1966 and the Ph.D. from the University of New Brunswick in 1975. In 1966 he joined the National Research Council of Canada and the following year he joined the Institute of Biomedical Engineering, UNB, as a Research Associate. In 1976 he was appointed to the Department of Electrical Engineering , UNB, and currently holds the rank of Hon. Research Professor in that department, and is a member of the Institute of Biomedical Engineering, UNB. His research interests are primarily in the area of biological signal processing.

MYOELECTRIC SIGNAL PROCESSING FOR CONTROL OF POWERED PROSTHESES

Parker, P., Englehart, K., and Hudgins, B.
Institute of Biomedical Engineering and Dept. of Electrical and Computer Engineering, University of New Brunswick, Fredericton, Canada

AIMS: To present an overview of myoelectric signal processing in the application of prosthesis control; to include historical perspective, state of the art, and future directions.

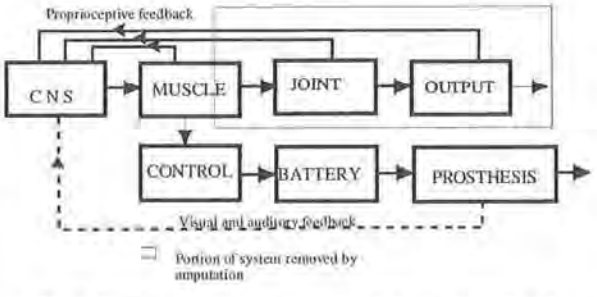
METHODS: The historical perspective will look at the developments in the field from the mid 1900s to 2006 with a break down by research and commercial activities. The state of the art will look at systems currently available and systems under development. The primary limitations of myoelctric control will be discussed including the issues of control site availability, control information estimation error, operator error, and sequential control. Future directions will look at current research activities and challenges.

RESULTS: The surface myoelectric signal is an effective and important system input for the control of powered prostheses. This control approach, referred to as myoelectric control, has found widespread use for individuals with amputations or congenitally deficient upper limbs. In these systems voluntarily controlled parameters of signals from a muscle or muscle group are used to select and modulate a function of a multifunction prosthesis. Figure 1 shows a block diagram schematic of the essential elements of a control system. The concept of myoelectric control was introduced in the 1940s; however the technology of the day was not adequate to make clinical application viable. During the 1960s through 1980s, with improved electronic technologies, significant progress was made in control development for on/off sequential control for one or two degree of freedom systems. In later years the emphasis has been on simultaneous independent control of multifunction systems using sophisticated pattern recognition techniques. The source of control signal for myoelectric controllers is viable residual muscle remaining following amputation or available muscle in the case of a congenital limb deficiency. Given a large superficial muscle it is possible to acquire signal from this muscle alone and achieve a single muscle control channel. For surface electrodes the limitations of the single muscle source include the requirement for a superficial muscle, the small interelectrode spacing, and in the case of the congenital amputee the uncertainty of muscle position.

Since the parameters under voluntary control are recruitment related the information to be extracted from the signal for control purposes should be derived from these parameters. Indeed, the combination of firing rate and pattern will impart a time sequence and parameter pattern to the signal that can also be extracted as information. Myoelectric controllers are therefore based on information derived from estimation of the signal variance and/or signal pattern. The first issue in this case is the method of choice for the estimation of variance, or another parameter related to the variance. The second is the prosthesis function selection and control algorithm based on the estimate. With respect to the first, the typical and reasonable approach is to estimate the signal mean-absolute-value (MAV). With respect to the second the process involves a decision algorithm to select and turn on/of or control proportionally one of a number of possible prosthesis functions. In practice, clinical systems can reliably control three functions, which is a limitation of the approach.

Repeatable recruitment patterns associated with individual limb motions/functions have the potential of being richer in information than the variance. It is then possible to provide control over more prosthesis functions for a given decision error. This becomes a pattern classification problem in which the control information is in the features of the pattern. For the single channel the features can be, for example, the coefficients of the autoregressive moving-average (ARMA) time series model of the signal. As advances are made in computing devices, signal processing techniques, and instrumentation, new possibilities for advancing the state-of-the-art in myoelectric control have arisen. The goals of current research in control are twofold: 1) to provide better accuracy in state selection, and 2) to present a more natural means of effecting control.

CONCLUSIONS: The limitation in all cases is the accuracy and rate of information that can be achieved via the myoelectric channel. Present commercial controllers place reasonably low demands on information, and can be accommodated by one or two channels. More sophisticated prostheses will require much higher rates and completely new control strategies. To these ends considerable work is directed to investigation of control strategies based on classification of signal patterns for continuous/simultaneous control of devices in multifunction prostheses.



Block diagram illustrating relationship between normal and myoelectric control systems (Shaded area is removed by amputation).

KEYNOTE LECTURE 1/THURSDAY, JUNE 29, 2006, SALA 500 (h. 14.00-15.00)

M. Solomonow, PhD, MD (hon), University of Colorado at Denver and Health Sciences Center Denver, Colorado, USA

Dr. Moshe Solomonow is a Professor and director of the Bioengineering Division and the Musculoskeletal Disorders research Laboratory in the Department of Orthopedics at the University of Colorado Health Sciences Center in Denver. He was a Professor and Director of Bioengineering and of The Occupational Medicine Research Center at Louisiana State University Health Sciences Center in New Orleans, Louisiana from 1983 to 2005.
He received the B.Sc., and M.Sc. in Electrical Engineering from California State University and the Ph.D. in Engineering Systems and Neuroscience from the University of California, Los Angeles.
Under his leadership, technology was developed for several translational projects related to; Myoelectric control of upper limb prosthetics for amputees; Electronic walking orthosis for paraplegics; Smart orthosis for Anterior Cruciate Ligament deficient patients; and smart braces for individuals with low back pain. He published over 130 refereed journal papers on musculoskeletal disorders including: motor control, Electromyography, muscle, tendon, ligament and joint Biomechanics, electrical muscle stimulation, prosthetics and orthotic systems for paraplegic locomotion, and supervised more than 150 engineering, physical therapy, medical students and orthopaedic residents, as well as postgraduate students and fellows from several countries.
Dr. Moshe Solomonow received the Crump Award for Excellence in Bioengineering Research (UCLA), the Distinctive Contribution Award from Delta 7 Society (France), The Doctor Medicine Honoris Causa (Vrije Universitiet, Brussels), The I. Cahen Professorship (LSUHSC) and the 1999 Volvo Award for Low Back Pain Research.

MUSCULOSKELETAL DISORDERS ASSOCIATED WITH THE SENSORY-MOTOR FUNCTION OF LIGAMENTS

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Bioengineering Section, Department of Orthopaedic Surgery
University of Colorado at Denver and Health Sciences Center, Denver, Colorado

Traditional perception defined the role of ligaments as a pure tension generating mechanical structure that keeps the bones associated with a joint in contact in the relevant segments of the range of motion. Speculations of a possible sensory role were offered over 100 years ago and non-conclusive experiments over 50 years later added to confusion. Early work from England identifying typical afferents (Golgi, Pacinian, Ruffini and Naked Endings) in some ligaments confirmed that some type of sensation, probably kinesthetic or proprioceptive is originating in ligaments.
With the wave of anterior cruciate ligament (ACL) ruptures and orthopaedic repairs in the 1980's, it became clear that repair of the ligament alone is not fully effective and that the ruptured ACL elicited a syndrome consisting of a disorder in the function of the muscles and the joint which culminated in osteoarthritis over time. In 1983 we initiated a long-term research program to identify the sensory elements in the major ligaments of the major joints; define their sensory-motor interaction with the associated structures; and the characteristic nature of the neuromuscular disorder elicited by various types of damage to ligaments.
The major findings over the last 20 years of research paint the following complicated but very insightful picture:
1. Most ligaments of the major joints contain afferents of the same type: Golgi, Ruffini, Pacinian and Bare nerves. These were found in the knee, shoulder, elbow, wrist / hand, ankle and spine.
2. There are three types of sensory afferents distribution: The first shows homogeneous distribution throughout the ligament, from insertion to insertion; the second type shows concentration of innervation at the two ends of the ligament, near its insertion into the bone; the third type demonstrates the complete absence of the sensory innervation or a very poor innervation. The first types give rise to sensory thresholds that is present from very low tension whereas the second type has a very high tension threshold due to the stiffer ligamentous tissue near the insertion. This in turn, defines two separate sensory roles; a continuous monitoring of length, tension, position, angle, etc. and an emergency signaling at very high tensions near risk of damage to tissues.
3. A fast, 1-3 ms long, reflex arc was identified from articular nerves emerging from the ligaments to muscles associated with the joint. This ligamento-muscular reflex (LM reflex) elicits contraction in muscles that tend to reduce the tension in the ligament, prevent joint instability and tissue damage. In the medial collateral ligament of the ankle, for example, stimulation of the articular nerve elicits contraction of the intrinsic muscles of the foot such that the foot arch is restored and ankle eversion is prevented. This also reduces the tension in the ligament. It is of note that none of the muscles that cross the ankle joint was activated by the LM reflex in this case.
4. Rupture of the ligament without damage to other nearby ligaments or tissues results in a period characterized by episodes of joint instability. With time or with training, a relearning process takes place and the joint may return to relatively stable operation although the ligament is absent.
In cases where other tissues in the joint (other ligaments, capsule, etc.) are damaged, a long term neuromuscular disorder may take place with atrophy of muscles, instability upon limb loading in simple daily tasks and fast onset of joint degeneration. Early signs of arthritis are seen even in joints that adapted to stable motion.
5. Short exposure of ligaments to static (constant stretch / load) or repetitive (cyclic load) activity results in the development of creep, decrease in the magnitude of LM reflex activity and muscular spasms. This renders the ligament and the joint as temporarily dysfunctional since the tension developed is lower and the feedback signals from the afferents are corrupted. A high risk of injury exists during this period.
6. The recovery of creep developed in a ligament over 1 hour of cyclic or static stretch to baseline length and tension may require more than 24 hours of rest at no load. The period of high risk is therefore, one hour immediately after loading / stretch with gradually reduced risk over the following 24 hours.
7. Some combinations of load, duration of load, number of sequential load repetitions and in-between rest can elicit an acute inflammation in the ligament with potential conversion to chronic inflammation if the tissue is continued to be exposed to work. The associated disorder consists of pain, limited range of motion, inability to sustain even light loads and sustained muscle spasms. Full recovery even after two years of rest is not observed.
In summary, ligaments subserve a critical role in movement; their mechanical properties consolidated with the neuro-sensory function subserves important functions in proprioception, kinesthesia and motor functions via the LM reflex. Joint stability is preserved by the ligaments with mechanical and elicited muscular forces and that is compromised by the damage to the tissues even by moderate static or cyclic loading. The resulting neuromuscular disorder could be short and minimal but could become chronic and debilitating if exposure is allowed over long periods of time.

Supported by NIOSH, NSF, and the LSU Board of Regents

KEYNOTE LECTURE 2 / FRIDAY, JUNE 30, 2006, SALA 500 (h. 08.00-09.00)

Dr. Machiel J. Zwarts, University Medical Center St. Radboud, Nijmegen, The Netherlands

Machiel J. Zwarts received his MD from the Faculty of Medicine, University of Groningen in 1978 and completed his residency in Neurology and Clinical Neurophysiology in 1984 at the University hospital, Groningen. In 1989 he received his PhD degree on the thesis "Applications of muscle fiber conduction velocity estimation" -A surface emg study-. Since 1997 he is professor of Clinical Neurophysiology at the Radboud University Medical Centre, Nijmegen, the Netherlands. In 1992 he was awarded the first "Storm van Leeuwen-Magnus prijs" of the Dutch society of Clinical Neurophysiology and in 2001 he presented the 26th Annual Edward H. Lambert Lecture on invitation of the American Association of Electrodiagnostic Medicine. He is chairmen of the Dutch Society for Clinical Neurophysiology and coauthor of the second edition of "Electrodiagnostic Medicine" (2002) by Dumitru D, Amato AA and Zwarts MJ. His research concerns the electrophysiological measurements and diagnosis of neuromuscular disorders and muscle fatigue. A major goal is the development and application of multi-channel surface electromyography as a new tool in the noninvasive diagnosis of neuromuscular disorders. Other areas of interest are ultrasound diagnosis of neuromuscular disease, magnetic stimulation of the nervous system, electrophysiological predictors of recovery, emg guided botulinum toxin treatment for movement disorders and central aspects of local muscle fatigue.

CLINICAL APPLICATIONS OF MULTI-CHANNEL SURFACE EMG: A REVIEW

G Drost, DF Stegeman, J P van Dijk,. MJ Zwarts.
Department of Clinical Neurophysiology Radboud University Nijmegen Medical Centre, The Netherlands

Traditionally, single channel surface EMG is used to measure the global output of the central nervous system during voluntary tasks. Usually, an arbitrary amplitude measure of the EMG signal was chosen for this purpose. An important limitation of these recordings is that electrical events are exclusively measured as a time-varying signal hampering the recognition of EMG activity at a single motor unit (MU) level. The development of multichannel surface EMG electrodes (up to 128 channels) has revolutionized surface EMG applications. In this review, the spatial aspect of the motor unit action potential (MUP) is emphasized in relation to the results of high-density, multichannel sEMG measurements. Using the multi-dimensional data it is now possible to extract information from the surface EMG at a single motor unit level. Essential to all further analysis is the recording of the signals in a monopolar fashion. In this way, off-line reconstruction of different montages is possible, both longitudinal and perpendicular to the muscle fiber direction. At low force levels, it is possible to extract MUPs using the spatio-temporal information. This results in a unique pattern of the amplitude distribution of the motor unit over the skin (finger print). The endplate zone, depth, size, position, conduction velocity, and firing pattern of MUs can be estimated. Present and future clinical applications of this technique are discussed.

KEYNOTE LECTURE 3 / FRIDAY, JUNE 30, 2006, SALA 500 (h. 14.00-15.00)

Prof. Paul Enck, University Hospital, Tuebingen, Germany

Director of Research, Dept. of Internal Medicine VI/ Psychosomatic Medicine and Psychotherapy, previously in the same position at the Dept. of General Surgery, University Hospitals, Tübingen, Germany; Trainied as a psychologist with focus on psychophyisology, neurophysiology, psychosomatics, and specialized in gastrointestinal function assessment including fecal incontinence.
More than 100 original data paper in scientific, peer-reviewed journals, more than 150 book chapters, review articles etc. More than 5 Million Euros in grant support from national and international bodies, numerouos industry-sponsered research projects.

AGE, INCONTINENCE SYMPTOMS, AND MODE OF DELIVERY AFFECT ANAL SPHINCTER EMG ASYMMETRY

Enck P[1], Hinninghofen H.[1], Kowalski A.[1], Merletti R[2], and Franz H[3].
1 Dept of Psychosomatic Medicine, University Hospitals Tübingen, Germany
2 LISiN, Dept. of Electronics, Politecnico di Torino, Italy
3 Gynaecology Clinic, Braunschweig Hospitals, Germany

AIMS: Surface-EMG (S-EMG) of external anal sphincter (EAS) by multi-electrode arrays (MEA) was used for a large series of gynecologic patients for the first time. We wished to determine the degree of asymmetry of sphincter innervation, its determinants, and the relationship to fecal incontinence.
METHODS: In 129 continent women following childbirth and in 40 patients with fecal incontinence recruited in a gynecological hospital (Vivantes Klinikum Berlin, Germany), S-EMG of the EAS was performed by 16-channel MEA during maximal voluntary contractions. Generation and propagation of individual motor unit actions potentials (MUAP) were recorded in the anal circumference at 3 levels within the anal canal. Innervation zones (IZ) of MUAP, their circular distribution in the quadrants as measure of symmetry, as well as the statistical characteristics of amplitude (ARV,RMS) and mean frequency (MNF) of power spectrum were compared between and across subgroups (age, continence status, number of deliveries) by ANOVAs.
RESULTS: All S-EMG characteristics were best identified in the proximal and distal anal canal, but ARV and the number of IZ were overall lower in incontinence, and differences between the three levels were less pronounced in incontinent patients. Age reduced independently the number of IZ ($p=.017$) and the amplitude (ARV, $p=0.046$). In incontinent subjects, lower amplitudes (RMS) ($p=.084$) and higher firing MNF ($p<0.001$) of EMG were found. Significant asymmetry of innervation was found for dorsal versus ventral, but not for left versus right comparison of amplitudes (RMS, $p=.004$) and frequency (MNF, $p=.001$), and was more pronounced in the distal anal canal for IZ distribution ($p=.007$) and in the proximal canal for EMG amplitude (ARV, $p=.007$). The asymmetry of power spectrum mean frequency (MNF) was increased with more deliveries, especially in incontinent women ($p=.026$). Episiotomy was asociated with significant left/right asymmetry of IZ distribution ($p=.075$), as was vacuum extraction ($p=.04$) and forceps delivery ($p=.04$), but not cesarian section (n.s.).
CONCLUSIONS: Asymmetry of innervation of the EAS seems to play a role in incontinence, with independent contribution of age, number of childbirth, and the mode of delivery.

KEYNOTE LECTURE 4 / SATURDAY, JULY 1, 2006, SALA 500 (h. 08.00-09.00)

Dr. Winfried Mayr, Dept of Biomedical Engineering and Physics, University of Vienna, Vienna, Austria

Winfried Mayr was born in Innsbruck in 1955. He received his Diploma degree in Electronics and Control Engineering from the Vienna University of Technology in 1983 and his Ph. D. in Biomedical Engineering in 1992. He is working at the Vienna University Medical School - Department of Biomedical Engineering and Physics - since 1983, from 1997 on as an Assistant Professor and since 2001 as an Associate Professor. His past and present research includes rehabilitation engineering in spinal cord injury, neural prostheses, and functional electrical stimulation (FES). He is currently co-ordinator of the EU FP5 R&D project "RISE" that deals with FES of denervated muscles.

NOVEL EMERGING APPLICATIONS IN FUNCTIONAL ELECTRICAL STIMULATION

Winfried Mayr
Center of Biomedical Engineering and Physics
Medical University of Vienna, Austria

The principle of evoking muscle contractions via electrical excitation of the related nerve has been known since the famous key experiments of Jan Swammerdam in 1658 and Luigi Galvani in 1790. The physiological knowledge to design both motor and sensory neuroprostheses was available in the 1930s. To enable the construction of small size battery powered devices for practical application, the invention of the transistor in 1948 and it's cheap availability by the end of the 1950s was required. This might be the main reason that most today's known clinical applications had been demonstrated in the 1950s and 1960s. A few of them like the cardiac pacemaker and cochlear implants have found their way into clinical routine. Some with clear medical indication and based on relatively simple technical equipment like the phrenic pacemaker or the sacral anterior root bladder controller have become accepted methods. Others that need multi-channel stimulators and complex control strategies have remained more or less in a stage of further development and clinical experiment.

Functional Electrical Stimulation (FES) is a generic term for a wide spectrum of applications. Beyond their common principle of electrical stimulation of excitable tissue these are characterized by a high degree of specialisation and interdisciplinary collaboration of clinicians, engineers, physiologists, and material and computer scientists with various types of expertise in vastly different backgrounds. After the earlier initial trials refinement strategies focus in increasingly complex technical equipment based on most actually available technology and aim in overcoming the acceptance and compliance problems associated with most of the traditional neuroprostheses. Real innovations and breakthroughs have become rather seldom in this field, the efforts show slow but steady progress towards improving equipment and methods.

There are a few novel applications of FES that have come out during the recent years and that seem more than promising. One is the stimulation of the spinal cord to control movement patterns generators. In contrast to the traditional approaches to control motor functions directly via stimulation this new method relies on pre-programmed neural structures and plasticity of the neuromuscular system by mimicking the lost brainstem control and providing necessary afferent inputs to elicit movement patterns. Recent clinical experiments demonstrate reproducible control of leg extension and stepping movements in paraplegic subjects. A second important advancement is the direct stimulation of the autonomic nervous system. Delivery of insulin as well as modulation of the blood pressure have been demonstrated just recently in impressive animal studies. The findings promise a high impact on the therapy of related diseases and an enormous breadth of potential applications. A third important innovation is the direct stimulation of denervated muscles. This topic is currently addressed by a European project that focuses on flaccid paraplegia includes basic animal research, development of test and stimulation equipment and the clinical application. Against the general belief for many years the project "RISE" was able to prove that it is possible to rebuild and maintain denervated muscles by FES even after years of denervation and associated muscle degeneration.

KEYNOTE LECTURE 5 / SATURDAY, JULY 1, 2006, SALA 500 (h. 14.00-15.00)

Prof. Francesco Felici IUSM, Roma, Italy

Dr. Felici is Associate Professor of Human Physiology and Exercise Physiology at the University Institute of Movement Sciences, Rome, Italy. He is a member of the Italian Physiological Society, of the International Society of Electromyography and Kinesiology, of the European College of Sport Sciences. He is member of the Editorial Board of the Journal of Electromyography and Kinesiology and of the Journal of Sports Medicine and Physical Fitness. Research activity focused mostly in the human movement area - from energetic to control - in collaboration with national and international institutions. The main topics are: Neuromuscular control. Non linear analysis of surface electromyograms. Neuromuscular effects of exercise and sport. Exercise Physiology in healthy and pathological subjects.

NEUROMUSCULAR RESPONSES TO EXERCISE INVESTIGATED THROUGH EMG

Francesco Felici, MD
Department of Human Movement and Sport Sciences
Istituto Universitario di Scienze Motorie, Roma, Italy

Thanks to the most recent progresses in surface electromyography (sEMG) data collection and analysis, also during dynamic contractions, there is no doubt that sEMG studies have provided relevant contributions to the understanding of human movement and, as a paradigmatic example, in the field of neuromuscular adaptations to exercise.
In this lecture, I will expand on some examples of sEMG applications in exercise physiology related to the description of results obtained from studies where only strictly non-invasive techniques (or of very limited invasivity) were applied. A consistent amount of space in this lecture will be dedicated to the advanced analysis of sEMG using non linear tools. Finally, I must stress that I will almost completely ignore, for the sake of brevity, all the methodological issues related to sEMG data capture and analysis during dynamic and static exercises.
Within the general framework of exercise physiology, it is possible to make a gross distinction between two main lines of sEMG application to the study of human movement and postures: (a) the non isometric exercise and (b) the isometric exercise. In the first case sEMG recording provides information about muscle activation patterns (i.e. timing of relative intervention), amplitude of myoelectric signal and, in short, a rough indication about muscles coordination during movement. Isometric contraction represents an attempt to reduce the confounding factors and variables to be controlled and, generally speaking, has a very poor relationship with the real life muscle action. The isometric case represents a sort of "simplified" version of movement. This allows the experimenter to overcame conceptual and practical problems related to the analysis of sEMG data collected during variable muscle length exercises. This is not obtained at low cost: the price to be paid is the lack of representativeness of the ordinary neural muscle control strategy.
When using sEMG to study exercise, an important aspect is raised by the particular design adopted to reproduce a given dynamic exercise. In other words, while measuring something in a laboratory environment, it is customary to devise a simplified version, a model, of the phenomenon under study. The ideal situation, however, should be represented by experiments in which the test exercise is the "actual" exercise, i.e. the experimental test exactly reproduces what happens outside the lab.
An alternative approach is represented by laboratory simulation of the exercise under investigation, as close to the real exercise as possible. This has been successfully exploited for very common exercises, such as walking, race walking, running, cycling, rowing among many others. A complete review of all these studies would expand well over the limits of this lecture.
Human deambulation, in its various forms, involves a series of coordinated movements of the body segments, implying an interplay of muscular forces and external forces (inertial, gravitational and reaction forces) in order to achieve locomotion of the body. The importance of having a complete and precise description of human walking is evident: this knowledge provided significant contributions in various fields: from rehabilitation to exercise. The results of the biomechanical data analysis, including sEMG data in the time domain, of normal walking on flat terrain can be summarized as follows: (a) there is no antagonistic muscular activity during the whole stride (except for the heel strike phase); (b) biarticular muscles are active only if this action is consistent with the moments required at the joints on which they act; (c) muscles are activated on lengthening (i.e. eccentric action eliciting reflex responses).
Stride-to-stride variability needs to be assessed before any particular stride is considered representative of subject's performance. Averaging multiple (possibly consecutive) stride data thus obtained will provide linear envelopes or ensemble averages of sEMG data. These can then be used to identify gait deviation or changes intervening because of fatigue, a change in speed of progression or walking style (from walking to race walking to running). Apart from the mere description of the activation phases of single muscles during a given motor task, these comparisons provide evidence of different motor control strategies in the three locomotion modalities studied.
Electromyography provided interesting results also for the characterisation of muscle adaptation to different running specialisation. In long distance runners and sprinters, a positive correlation between muscle fibre action potential conduction velocity (CV) and the percentage of FT fibre areas was found. This means that muscles with a higher percentage of FT fibre area had higher CVs with respect to muscles with a lower percentage of FT fibre area. From this work emerges that power athletes (sprinters) have higher CVs than resistance athletes (long distance runners). An important and still open question arises from this and similar studies, i.e. can training modify the amount of a specific type of muscle fibre in the target muscle or muscle group? It must be stressed, that also sEMG ability in sensing specific muscle adaptation to training is still under study.
Physiological mechanisms of adaptation to strength and power training include a variety of aspects, from morphological to functional. Surface EMG has been largely used to study the adaptations of the neuromuscular system to heavy resistance training and to examine the adaptational time course for these changes. It is evident that although sEMG investigates only and indirectly the lowest part, i.e. the -motoneuron level, of the complex motor command system, sEMG studies have provided the most direct evidence of neural adaptation to training. However, considering the many factors that affect sEMG signal and their interactions, inferences on neural motor control modifications due to a specific training protocol can be made only with extreme care. This is reinforced by the fact that strength/power training protocols can be differently configured and can be described in terms of five (acute) program variables: 1) type of exercise; 2) order of the exercise; 3) resistance or intensity adopted; 4) number of repetitions per set; 5) rest period length between sets. Because of the many possible configurations of training protocols, apart from being exercise specific muscle adaptations are also thought to be protocol-specific. Finally, it has been recently shown that loading protocols affect not only the active neuromuscular

response to training, but also exert an important influence on muscle reflex responses and susceptibility to damage. It must be kept in mind that the vast majority of published papers on the neuromuscular adaptations to strength training have been performed on untrained subjects, usually students.

Experienced weight lifting athletes represent a good model for the study of neuromuscular adaptation occurring when a subject is seriously trained to strength (as opposed to laboratory training protocols). Some research partially attributed the enhancement in strength of weight-trained subjects to an increase in MUs recruitment and firing rate of motor units. Furthermore, structural adaptations of muscle fibres can imply a change in muscle fibre CV. A greater MU synchronisation in weight lifting athletes with respect to untrained persons is well documented . Besides the enhanced MU synchronisation, common simultaneous fluctuations in MU firing rate have been described, which were much more pronounced in strength trained than in controls and minimal in skilled trained subjects. We recently confirmed these results and, in the same work, we also showed greater myoelectric manifestations of muscle fatigue in weight lifters with respect to controls. This should indicate a greater and more precocious recruitment of FT fibres in well-trained power athletes.

We applied a new analytical tool to the sEMG, namely a non-linear approach called recurrence quantification analysis (RQA). One of the variables obtained by RQA analysis, the percentage of determinism (%DET) is effective in detecting subtle changes of the underlying dynamics in sEMG signal attributable to ongoing changes in muscle activation. In particular, during continuous heavy isometric contractions, the increase in %DET has been taken as an index of myoelectric fatigue. In weight lifters, even in the cases where evident muscular burst activity was not observed, a %DET increase was noted; conversely, in the controls this %DET modification was not observed. A prevalent MUs synchronization seems to be a special feature of people trained for brief, maximal efforts. It may be speculated about the usefulness of any sort of synchronisation in improving the force output; it does not seem convincing that increasing synchronisation or common drive can increase the force output. Conversely, grouping of firings could be effective in increasing the rate of force development during brief maximal contractions producing maximal acceleration of the barbell when body lever arms are in the most efficient position as at the start of lifting. Results provided by the RQA can be interpreted as a peculiar neuromuscular adaptation in these athletes, which seems to have developed a particular ability in activating their muscles as swiftly and completely as possible. We recently added further support to this view, working with simulated and real sEMG signals, showing that %DET senses MU synchronization while CV does not.

This result seems of particular relevance, in that indicates that a combined use of linear and non linear analytical techniques can be foreseen as producing significant advances in the non invasive assessment of neuromuscular function.

INTEGRATED MOVEMENT ANALYSIS IN SPORT AND EXERCISE / ROME JULY 3-4, 2006

The course will take place at the University Institute for Movement Sciences (IUSM) in Rome on 3 - 4 July 2006. The objective of the course is to make the participants familiar with the most up-to-date techniques and methods for integrated movement analysis for the characterization of sport and exercise activities. Participants will perform their hand-on personal experiments, from data collection to analysis. The course is aimed at Medical doctors, Biomedical engineers, Physical Therapists, Sport Scientists. Doctoral students of the above listed fields are welcome. The number of participants will be between 30 and 50 (The course will not be activated with less than 30 registrants).

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Course web site: (http://www.iusm.it/didattica/permanente/pagina/permanente.html)
at the page Integrated Movement Analysis in Sport and Exercise.

Post-Congress Course

Scientific Program

THURSDAY, JUNE 29, 2006

Sala 500

h 08.30-09.00 Wellcome of the Authorities
(A. Bairati, *Councillor for Research, Regione Piemonte, Italy* and F. Profumo, *Rector of Politecnico di Torino, Torino, Italy*)

h 09.00-09.30 Opening speech
(R. Merletti, *Congress Chair* and C. Disselhorst-Klug, *ISEK President*)

h 09.30-10.30

Sala 500

BASMAJIAN LECTURE: Phil Parker
Myoelectric signal processing for control of powered prostheses

h 10.30-14.00 POSTER MOUNTING. Posters will remain visible for the entire duration of the Congress

h 10.30-11.00 COFFE BREAK

h 11.00-12.45 ORAL PRESENTATIONS

Sala 500

Rehabilitation Engineering (*Chairs: Solomonow M, Linnamo V*)

FUNCTIONAL ELECTRICAL THERAPY (FET) OF WALKING
Popovic DB, Popovic MB

QUANTIFYING PROPRIOCEPTIVE REFLEXES AROUND THE WRIST IN PATIENTS WITH COMPLEX REGIONAL PAIN SYNDROME
De Graaf WW, Munts AG, Van Hilten JJ, Schouten AC, Veeger HEJ, Van der Helm FCT

ESTIMATION OF HUMAN MUSCLE FORCE DYNAMIC RESPONSE USING A SHORT FEW SECONDS STIMULATION PROTOCOL
Gobbo M, Diemont B, Orizio C, Solomonow M

ASSESSING THE RECOVERY OF POSTSTROKE PATIENTS USING ROBOT-AIDED TECHNIQUES
Colombo R, Pisano F, Mazzone A, Delconte C, Micera S, Carrozza MC, Dario P, Minuco G

A GAZE-DETECTION SYSTEM BASED ON A NOVEL NEURAL APPROACH
Torricelli D, Goffredo M, Conforto S, Schmid M

MULTI-CHANNEL SURFACE EMG FOLLOWING NERVE-MUSCLE REINNERVATION OF THE PECTORALIS MUSCLES IN A SHOULDER DISARTICULATION AMPUTEE
Lowery MM, Zhou P, Englehart KB, Kuiken TA

TARGETED REINNERVATION FOR IMPROVED PROSTHETIC FUNCTION
Kuiken T, Dumanian G, Lipschutz R, Miller L, Stubblefield K

Sala Londra

Motor Control (*Chairs: Graven Nielsen T, Roatta S*)

SYMPATHETIC MODULATION OF MUSCLE FUNCTION: OVERVIEW AND UPDATE
Roatta S, Passatore M

UPPER TRAPEZIUS MUSCLE PAIN RESULTS IN REORGANIZATION OF COORDINATION AMONG TRAPEZIUS MUSCLE SUBDIVISIONS DURING DYNAMIC MOVEMENT OF THE UPPER LIMB
Falla D, Farina D, Graven-Nielsen T

FACILITATION OF STRETCH REFLEX IN HUMAN SOLEUS MUSCLE DURING PASSIVE STANDING
Shimba S, Kawashima N, Yamamoto S-I, Nakazawa K

TASK-DEPENDENT REFLEX CONTRIBUTIONS TO MULTIJOINT COORDINATION
Perreault EJ, Chen K

HETERONYMOUS REFLEX CONTRIBUTIONS TO MUSCLE ACTIVITY IN THE UPPER LIMB
Perreault EJ, Chen K

SPINAL REFLEXES OPTIMALLY ADAPT TO UNSTABLE ENVIRONMENTS
Schouten AC, De Vlugt E, Van der Helm FCT

Sala Madrid

Multichannel EMG and electrode arrays (*Chairs: Rau G, Sadoyama T*)

OPTIMAL MONO- AND BIPOLAR ELECTRODE LOCATIONS IN FACIAL ELECTROMYOGRAPHY DETERMINED BY SINGLE MOTOR UNIT ANALYSIS
Lapatki BG, Oostenveld R, van Dijk JP, Jonas IE, Zwarts MJ, Stegeman DF

SPATIAL REORGANISATION OF UPPER TRAPEZIUS MUSCLE ACTIVTY IN PRESENCE OF EXPERIMENTAL MUSCLE PAIN
Madeleine P, Leclerc F, Arendt-Nielsen L, Ravier P, Farina D

PRELIMINARY SIMULATION RESULTS OF A METHOD FOR OPTIMIZING SPATIAL FILTERS IN HIGH-RESOLUTION ELECTROMYOGRAM ARRAYS
Quartararo JD, Clancy EA

MUSCLE FIBER ORIENTATION ESTIMATION USING A 2-DIMENSIONAL ELECTRODE ARRAY
Martin S, MacIsaac D, Parker P

A COMPARISON OF SURFACE AND INTRAMUSCULAR MYOELECTRIC SIGNAL CLASSIFICATION
Hargrove LJ, Englehart K, Hudgins B, Lecke R

DISTINCTION BETWEEN NECK-SHOULDER PAIN CASES AND HEALTHY CONTROLS WITH COMBINED MULTICHANNEL EMG PARAMETERS
Kallenberg LAC, Hermens, HJ, Vollenbroek-Hutten MMR

NON-INVASIVE EVALUATION OF UTERUS ACTIVITY DURING LABOR USING A DYNAMIC MAPPING SYSTEM
Garcia-González MT, Charleston-Villalobos S, Aljama-Corrales T, González-Camarena R, Vargas-García C

h 12.45-14.00 LUNCH

h 14.00-15.00

Sala 500 KEYNOTE LECTURE 1: Moshe Solomonow
Musculoskeletal disorders associated with the sensory-motor function of ligaments

h 15.15-16.30 ORAL PRESENTATIONS

Sala 500 **Application in ergonomics (Chairs: *Sjogaard G, Sandsjö L*)**

FORCE AND ELECTROMYOGRAPHY DURING SQUAT AND STOOP LIFTING, PUSH AND PULL
Vieira ER, Kumar S

OBESITY AFFECTS TRUNK POSTURE AND LOAD DURING A STANDING WORK TASK
Gilleard W, Smith T

EVALUATION OF VEHICLE DRIVEABILITY BY USING DRIVER'S SURFACE EMG
Kuramori A, Kamijo M, Sadoyama T

SURFACE ELECTROMYOGRAPHY RECORDINGS OF CAR DRIVERS AND PASSENGERS SUBJECTED TO LATERAL ACCELERATIONS
Farah G, Hewson D, Duchêne J

NEUROMUSCULAR DEMANDS ON MASSAGE THERAPIST'S PERFORMING CORPORATE MASSAGES
Albert WJ, Kuruganti U, Buck F, Babineau M, Orser S, Currie-Jackson N

Sala Londra **Motor Control (*Chairs: Hodges P, Schieppati M*)**

THE EFFECTS OF ACTIVE AND PASSIVE TRUNK STIFFNESS ON SPINE CONTROLLABILITY
Reeves NP, Everding V, Cholewicki J, Morrisette DC

DIFFICULTIES IN ADJUSTING MUSCLE ACTIVATION PATTERNS TO STABILIZE THE SPINE UNDER EXTERNALLY LOADED SITUATIONS
Brown SHM , Vera-Garcia FJ, McGill SM

DEEP AND SUPERFICIAL ABDOMINAL MUSCLES SHOW DIFFERENT ACTIVATION PATTERNS IN A HOLD-RELEASE SITUATION
Eriksson Crommert M, Thorstensson A

NEUROMUSCULAR INDEPENDENCE OF THE ABDOMINAL WALL AS DEMONSTRATED BY MIDDLE-EASTERN STYLE DANCERS
Flynn JM, Vera-Garcia FJ, McGill SM

LUMBOPELVIC MUSCLE RESPONSES TO PROGRESSIVE LOADING AND REDUCED PREDICTABILITY
McCook D, Coppieters MW, Vicenzino B, Hodges PW

Sala Madrid **Mechanomyogram (*Chairs: Moritani T, Orizio C*)**

TWO-DIMENSIONAL SPATIAL DISTRIBUTION OF SURFACE MECHANOMYOGRAPHY RESPONSE TO SINGLE MOTOR UNIT ACTIVITY
Cescon C, Madeleine P, Graven-Nielsen T, Merletti R, Farina D

EFFECT OF SKIN TEMPERATURE ON ELECTROMYOGRAM AND MECHANOMYOGRAM DURING BRIEF ISOMETRIC CONTRACTION
Mito K, Kaneko K, Makabe H, Shimizu Y, Sakamoto K

MECHANOMYOGRAPHIC TOPOGRAPHICAL MAPS IN ISOMETRIC CONTRACTIONS
Madeleine P, Cescon C, Farina D

INFLUENCE OF INSTANTEOUS DISCHARGE RATE ON MOTOR UNIT CONTRIBUTION TO MECHANOMYOGRAM
Gobbo M, Madeleine P, Cescon C, Orizio C, Farina D

h 16.30-17.30 COFFE BREAK and **POSTER SESSIONS: EMG Modeling (T01), EMG Signal Processing (T02), Multichannel EMG and electrode arrays (T06), Mechanomyogram (T08), Technology transfer (T18).**

EMG Modeling (T01)

T01.P01. SIMULATION OF SURFACE EMG SIGNALS FOR A MULTI-LAYER VOLUME CONDUCTOR WITH TRIANGULAR MODEL OF THE MUSCLE TISSUE
Mesin L

T01.P02. ESTIMATION OF MUSCLE FIBER CONDUCTION VELOCITY IN PINNATE MUSCLES: A SIMULATION STUDY
Mesin L, Farina D

T01.P03. A FINITE ELEMENT MODEL FOR DESCRIBING THE EFFECT OF MUSCLE SHORTENING ON SURFACE EMG
Mesin L, Joubert M, Hanekom T, Merletti R, Farina D

T01.P04. AN ANALYTICAL MODEL FOR SURFACE EMG GENERATION IN VOLUME CONDUCTORS WITH SMOOTH VARIATION IN CONDUCTIVITY
Mesin L, Farina D

T01.P05. ESTIMATION OF NERVE FIBER CONDUCTION VELOCITY DISTRIBUTIONS WITH INGRAM'S COLLISION TECHNIQUE: RESULTS OF A COMBINED NERVE-MUSCLE MODEL
Hennings K, Farina D

T01.P06. A SIMULATION STUDY FOR A SURFACE EMG SENSOR THAT DETECTS DISTINGUISHABLE MOTOR UNIT ACTION POTENTIALS
Adam A, Lee J, De Luca CJ

T01.P07. RELATIONSHIP BETWEEN RESTRICTION OF CHEWING MOVEMENT FUNCTION AND 8- HYDROXY-2 '-DEOXYGUANOSIN
Kubota A, Takeda H, Takayanagi K, Hosoda M, Isozaki K, Nishihara K, Taguchi T, Inoue K, Hosoda K, Morita S

T01.P08. EFFECTS OF BONDED RAPID MAXILLARY EXPANSION APPLIANCES ON MASTICATORY MUSCLES PERFORMANCE DURING MASTICATION
De Rossi M, Vitti M, Semprini M, De Rossi A, Gavião MBD, Santos CM, Regalo SCH

T01.P09. ESTIMATION OF PARAMETERS IN THE DIMITROV-DIMITROVA SFAP MODEL
Rodríguez J, Malanda A, Gila L, Navallas J, Rodríguez I

T01.P10. PROPOSAL FOR ELECTRICAL INSULATION OF THE SIGNAL ACQUISITION MODULE
Forti F, Guirro RRJ, Rodrigues D

T01.P11. BEHAVIOR OF THE ELECTROYMYOGRAPHIC VARIABLES ALONG THE THICKEST PART OF THE MUSCLE
Forti F, Guirro RRJ

T01.P12. EFFECT OF DEAFNESS ON MASTICATORY CYCLE EFFICIENCY: ELECTROMYOGRAPHIC ANALYSIS
Semprini M, Regalo SCH, Mathias V, Hallak JEC, Ribeiro LR, Santos CM, De-Rossi M, Galo R, Siéssere S, Felício CM, Oliveira AS

T01.P13. BEHAVIOR OF THE EMG SIGNAL DURING ISOMETRIC ACTION IN INCREMENTED RESISTED EXERCISE
de Aguiar AP, Rodrigues D, Cobos Stefanelli V, de Oliveira JC, Baldissera V

EMG Signal Processing (T02)

T02.P01. IDENTIFICATION OF NON-PROPAGATING COMPONENTS IN SURFACE EMG RECORDINGS BY OPTIMAL SPATIAL FILTERING
Mesin L, Tizzani F, Farina D

T02.P2. SEPARATION OF PROPAGATING AND NON-PROPAGATING COMPONENTS IN SURFACE EMG
Mesin L, Kandoor AKR, Merletti R

T02.P3. ESTIMATION OF MOTOR UNIT CONDUCTION VELOCITY DISTRIBUTION BY MULTI-CHANNEL M-WAVE DECONVOLUTION
Mesin L, Pandolfi L, Farina D

T02.P4. ASSESSMENT OF STABILITY OF PERIODIC MUSCLE CONTROL IN RUNNING BY PULSE COUNTING PROCESSING OF ELECTROMYOGRAM
Imaizumi K, Hiki S

T02.P5. KNOWLEDGE-BASED AUTOMATIC DECOMPOSITION OF EMG SIGNALS
Marateb HR, McGill KC

T02.P6. MOTOR UNIT RECRUITMENT IN REFLEXIVELY ACTIVATED MULTIFIDUS MUSCLE OF FELINE MODELS
Arabadzhiev TI, Solomonow M, Zhou BH, Dimitrova NA, Dimitrov GV

T02.P7. USING TORQUE AND MYOELECTRIC SIGNAL DATA TO EXAMINE THE BILATERAL LIMB DEFICIT PHENOMENON IN FEMALES OF DIFFERENT AGES
Kuruganti U, Parker P, Tingley M

T02.P8. RELIABILITY OF RECURRENCE ANALYSIS TO EXTRACT SYNCHRONOUS FIRING FROM SURFACE MYOELECTRIC SIGNAL
Del Santo F, Gelli F, Mazzocchio R, Spidalieri R, Rossi A

T02.P9. STREAMING TOPOGRAPHIC MAPPING OF LUMBAR MYOELECTRIC ACTIVITIES
Mak JNF, Hu Y, Luk KDK

T02.P10. EVALUATION OF INFLUENCE OF ECG INTERFERENCE ON SEMG ASSESSMENT OF LOW BACK MUSCLES
Mak JNF, Hu Y, Luk KDK

T02.P11. RESOLUTION OF SUPERIMPOSED MUAPS WITH A GENETIC ALGORITHM
Florestal JR, Mathieu PA, Plamondon R

T02.P12. EFFECTS OF EMG PROCESSING ON BIOMECHANICAL MODEL OF MUSCLE JOINT SYSTEMS
Staudenmann D, Potvin JR, Kingma I, Stegeman DF, van Dieën JH

T02.P13. MUAP DURATION ALGORITHM BASED ON THE WAVELET AND HILBERT TRANSFORMS
Rodríguez I, Malanda A, Navallas J, Rodríguez J, Gila L, García-Gurtubay I, Mallor F, Gómez S

T02.P14. PROCESSING TO IMPROVE EMG-BASED FORCE ESTIMATES FROM FATIGUED MUSCLES
Cort JA, Cashaback J, Potvin JR

T02.P15. ANALYSIS OF REGRESSION STRAIGHT LINE ANGLE DISPLACEMENT IN RELATION BETWEEN SURFACE ELECTROMYOGRAM AND JOINT TORQUE
Nitta O, Ynagisawa K

T02.P16. MUSCLE ACTIVITY DURING APPROACH RUN OF SKI JUMPING IN TERMS OF POSTURE CONTROL
Murayama T, Mori S, Kobayashi M, Ushiyama Y, Kiryu

T02.P17. WAVELET ANALYSIS OF EMG WAVEFORM RELATED TO SPONTANEOUS AND VOLUNTARY BLINKS
Kaneko K, Mito K, Makabe H, Sakamoto K

T02.P18. A NEW DEVICE TO MEASURE THE ELETROMYOGRAPHIC SIGNALS EASILY
Yasukouchi A, Tukamoto K, Shin D, Sato M, Koike Y

T02.P19. ESTIMATING SQUARE-SHAPED TERRITORY OF SINGLE MOTOR UNITS USING SURFACE ELECTROMYOGRAMS
Akazawa J, Sato T, Minato K, Yoshida M

T02.P20. CLINICAL DECISION SUPPORT BY FUZZY LOGIC ANALYSIS OF QUANTITATIVE ELECTROMYOGRAPHIC DATA
Hamilton-Wright A, Stashuk DW

T02.P21. WAVELET ANALYSIS REFLECTS THE INTERPLAY OF HIGH AND LOW EMG FREQUENCY COMPONENTS WHILE RUNNING
von Tscharner V

Multichannel EMG and electrode arrays (T06)

T06.P1. EXTRACTION OF MOTOR UNIT ACTION POTENTIAL TRAINS FROM MULTI-CHANNEL ELECTROMYOGRAPHIC SIGNALS BASED ON STATISTICAL ANALYSES
Nakamura H, Yoshida M

T06.P2. MAPPING OF THE JAW-STRETCH REFLEX EMG ACTIVITY IN THE HUMAN MASSETER
Koutris M, Wang K, Lobbezoo F, Leclerc F, Naeije M, Svensson P, Farina D

T06.P3. BEHAVIOUR OF MOTOR UNIT ACTION POTENTIAL RATE, ESTIMATED FROM SURFACE EMG, AS MEASURE FOR MOTOR CONTROL
Kallenberg LAC, Hermens HJ

T06.P4. ANALYSIS OF FOREARM MUSCLES DURING GRIPPING EXERCISE BY MEANS OF LINEAR ELECTRODE ARRAYS AT DIFFERENT LEVELS OF EFFORT
Rojas M, Mañanas MA, Chaler J

T06.P5. EVIDENCE OF POTENTIAL AVERAGING OVER THE FINITE SURFACE OF A BIOELECTRIC ELECTRODE USING HIGH-DENSITY EMG
van Dijk JP, Stegeman DF, Lapatki BG, Zwarts MJ

Mechanomyogram (T08)

T08.P1. THE ESTIMATION METHOD OF MAXIMUMVOLUNTARILY CONTRACTION FORCE BASED ON MECHANOMYOGRAM
Hara Y, Yoshida M, Minato K

T08.P2. TIME-FREQUENCY ANALYSIS OF NONSTATIONARY MECHANOMYOGRAM RECORDING DURING SUSTAINED ISOMETRIC CONTRACTION OF BICEPS BRACHII MUSCLES
ItohY, Akataki K, Mita K, Watakabe M, Suzuki N

T08.P3. MEASUREMENT OF ACCELERATION / DISPLACEMENT MMG IN TETANIC CONTRACTION
Oka H, Watanabe S, Kitawaki T

T08.P4. TETANIC CONTRACTION PROPERTIES OF DIFFERENT MUSCLE FIBERS
Watanabe S, Kitawaki T, Oka H

T08.P5. MODULATION OF EMG AND MMG SIGNALS DURING A RAMP CONTRACTION OF THE KNEE EXTENSORS
Dell'Oso F, Arsenault AB, Requião L, Orizio C

T08.P6. COHERENCE ANALYSIS BETWEEN MECHANOMYOGRAM AND ELECTROMYOGRAM OF THE BICEPS BRACHII DURING MAXIMAL ISOMETRIC VOLUNTARY CONTRACTION
Kisiel-Sajewicz K, Najwer W, Marusiak J, Dabrowski A, Yue G, Jaskólska A, Jaskólski A

T08.P7. THE ESTIMATION OF MECHANICAL PROPERTY BY THE FREQUENCY ANALYSIS OF THE MECHANOMYOGRAM
Yoshida M, Hara Y

T08.P8. A BIOMECHANICAL INVESTIGATION ON VIBRATION TRANSDUCERS IN MECHANOMYOGRAPHY
Watakabe M, Mita K, AkatakiK, Itoh Y, Atsuta Y

T08.P9. MECHANOMYOGRAPHIC DETERMINATION OF POST-ACTIVATION POTENTIATION IN MYOPATHIES
Akataki K, Mita K, Ng AR, Arimura K

Technology transfer (T18)

T18.P1. ELECTRO-MECHANICAL STABILITY OF SURFACE EMG SENSORS
De Luca G, Roy SH, Cheng S, Bergman P, Johansson A, Gilmore D, De Luca CJ

h 17.30-18.30 ORAL PRESENTATIONS

Sala 500 **Virtual and augmented reality in rehabilitation(*Chairs: Bonato P, De Rossi D*)**

REGULATION OF BALANCE UNDER CONCORDANT AND DISCORDANT SOMATOSENSORY AND VISUAL PERTURBATIONS
Bugnariu N, Fung J

VISUAL CONTEXT INFLUENCES INTERSEGMENTAL COORDINATION IN HEALTHY YOUNG AND ELDERLY ADULTS
Keshner EA, Kenyon RV, Gurses S

STIMULATION THROUGH SIMULATION: MENTAL PRACTICE WITH VIRTUAL REALITY FOR POST-STROKE REHABILITATION
Giaggioli A, Morganti F, Meneghini A, Alcaniz M, Lozano JA, Contesa J, Martínez Sáez JM, Walker R, Lorusso I, Riva G

INVESTIGATING ADVANCED MYOELECTRIC CONTROL FOR MULTIFUNCTION UPPER-EXTERMITY PROSTHESES USING VIRTUAL REALITY
Lock BA, Englehart K, Hudgins B

Sala Londra **Motor Units (*Chairs: Enoka R, Gazzoni M*)**

MULTIPLE MOTOR UNIT DISCHARGES IN AN INTRINSIC MUSCLE OF TRANSPLANTED HAND
Farina D, Pozzo M, Lanzetta M

DOUBLET DISCHARGES ARE DEPENDENT ON MOTOR UNIT FIRING RATES IN MOTONEURONS OF YOUNG AND OLDER HUMANS
Christie A, Kamen G

DECOMPOSITION OF SURFACE EMG SIGNALS
De Luca CJ, Wotiz B, Adam A, Nawab SH

MULTI-CHANNEL THIN-FILM ELECTRODE SYSTEMS FOR INTRAMUSCULAR EMG RECORDINGS
Yoshida K, Farina D

Sala Madrid **Muscle Fatigue (*Chairs: Parker P, Rainoldi A*)**

RELATIONSHIP BETWEEN MECHANICAL POWER AND FREQUENCY BEHAVIOUR FOR HIGHLY NON STATIONARY SIGNALS USING DISCRETE WAVELET
Silvestre R, Letelier JC

CONDUCTION VELOCITY MEASUREMENT IN THE GENIOGLOSSUS MUSCLE DURING FATIGUING CONTRACTIONS
O'Connor C, Langran S, O'Sullivan M, Nolan P, O'Malley M

DOES LOW AND HIGH FREQUENCY STIMULATION ITSELF CAUSE MUSCLE FATIGUE: IMPLICATION FOR MEASUREMENT
Johnson PW

DIFFERENTIAL ACTIVATION OF REGIONS WITHIN A SINGLE MUSCLE DURING FATIGUE
Holtermann A , Grönlund C , Karlsson JS, Roeleveld K

h 18.30-20.30 Meeting of the JEK Editorial Board (Sala Praga)

FRIDAY, JUNE 30, 2006

h 08.00-09.00

Sala 500 KEYNOTE LECTURE 2: Machiel J Zwarts
Clinical applications of multi-channel surface EMG: a review

h 09.15-10.45 ORAL PRESENTATIONS

Sala 500 **Neurophysiology (*Chairs: Zwarts M, Schieppati M*)**

THE RECRUITMENT ORDER OF ELECTRICALLY ACTIVATED MOTOR NEURONS INVESTIGATED WITH A NOVEL COLLISION TECHNIQUE
Hennings K, Kamavuako NE, Merletti R, Farina D

IDENTIFICATION OF MAXIMAL M-WAVE DURING TRANSCUTANEOUS STIMULATION IN HUMAN TIBIALIS ANTERIOR
Orizio C, Merlo E, Merletti R

ARCHITECTURE OF A SERIES-FIBERED HUMAN MUSCLE: EMG STUDY OF BRACHIORADIALIS
Lateva ZC, McGill KC

THE EFFECT OF MUSCLE CO-CONTRACTION ON STRETCH REFLEX RESPONSES IN MUSCLES CROSSING THE ELBOW
Lewis GN, Settle K, MacKinnon CD, Perreault EJ

INTROSPECTIVE KINESTHETIC ILLUSION ACTIVATES MOTOR EXECUTION SYSTEM MORE STRONGLY THAN SIMPLE ACTION OBSERVATION IN HUMAN
Kaneko F, Yasojima T, Kizuka T

THE BRAIN SYMMETRY INDEX AS A FEATURE FOR A BRAIN COMPUTER INTERFACE
ten Hoedt MJM, van Putten MJAM

Sala Londra **EMG Signal Processing (*Chairs: Parker P, Kiryu T*)**

NONINVASIVE ANALYSIS OF MOTOR UNIT DISCHARGE PATTERNS IN ISOMETRIC FORCE-VARYING CONTRACTIONS
Holobar A, Zazula D, Gazzoni M, Merletti R, Farina D

AN ALGORITHM FOR OPTIMAL DISCHARGE SELECTION FOR MUAP WAVEFORM EXTRACTION
Navallas J, Malanda A, Gila L, Rodríguez J, Rodríguez I, Florestal JR, Mathieu PA

BLIND OPTIMIZATION OF WAVELETS FOR SEPARATION OF NON-STATIONARY SURFACE EMG SIGNALS
Farina D, Lucas MF, Doncarli C

INDEPENDENT COMPONENT ANALYSIS AND HIGH-DENSITY EMG GRID IN MUSCLE FORCE ESTIMATION
Staudenmann D, Kingma I, Daffertshofer A, Stegeman D.F, van Dieën JH

ENTROPY-BASED OPTIMIZATION OF SPATIAL SELECTIVITY IN SURFACE EMG DETECTION WITH WAVELET SPATIAL FILTERS
Wu J, Naddeo F, Farina D

AN EXPERT SYSTEM TO SUPPORT THE INTERPRETATION OF SURFACE EMG IN GAIT ANALYSIS
Heinze F, Schmitz-Rode T, Rau G, Disselhorst-Klug C

Sala Madrid **Muscle Fatigue (*Chairs: Roy S, Minetto M*)**

ASSESSMENT OF MYOELECTRIC MANIFESTATIONS OF FATIGUE IN THE VASTUS LATERALIS AND MEDIALIS MUSCLES
Rainoldi A, Falla D, Mellor R, Bennell K, Hodges P

PHYSIOLOGICAL CHARACTERISTICS OF MOTOR UNITS IN THE BRACHIORADIALIS MUSCLE ACROSS FATIGUING LOW-LEVEL ISOMETRIC CONTRACTIONS
Calder KM, Stashuk DW, McLean L

CENTRAL MOTOR CONTROL FAILURE IN FIBROMYALGIA SYNDROME: A SEMG ASSESSMENT OF TREATMENT EFFECTIVENESS
Casale R, Gazzoni M, Rainoldi A

PRELIMINARY DEVELOPMENT OF A NEW EMG-BASED TEST TO ASSESS THE CAPACITY OF BACK MUSCLES
Larivière C, Arsenault AB, Gravel D, Gagnon D, Gardiner P, Loisel P

BACK MUSCLE FORCE, ENDURANCE AND FATIGABILITY IN RECURRENT LBP CASES FROM NURSING AND ADMINISTRATIVE PROFESSIONS
Schenk P, Läubli T

ELECTROMYOGRAPHY STUDY ABOUT BUCCINATOR AND MASSETR MUSCLES IN SUBJECTS ANGLE CLASS I AND III
Nagae MH, Bérzin F, Corrêa ECR

h 10.45-11.45 COFFE BREAK and **POSTER SESSIONS: Motor Control (T07), Motor Units (T09), Muscle Fatigue (T10), Neurophysiology (T11)**

Motor Control (T07)

T07.P1. HIERARCHICAL CONTROL OF GOAL-DIRECTED MOVEMENTS
Popovic MB, Popovic DB

T07.P2. THE INFLUENCE OF PACED SOUND IN A FINGER OPPOSITION TASK ON THE ACTIVATION OF SUPPLEMENTARY MOTOR AREA AND CEREBELLUM: A FMRI STUDY
Watanabe S, Kuruma H, Matsuda M, Abo M, Kikuchi Y, Seno A, Ikeda Y, Yonemoto K

T07.P3. VISUAL EFFECTS ON MUSCLE ACTIVATION OF LOWER LIMB IN YOUNG HEALTHY SUBJECTS DURING DROP LANDINGS
Yang C-H R, Guo L-Y, Tsao H, Deng H-R, Gong W-Y, Hodges PW

T07.P4. BRAIN STRUCTURES CORRELATES TO FINGER TAPPING USING NEAR INFRARED SPECTROSCOPY
Furusawa AA, Onishi H, Soma T, Kurokawa Y

T07.P5. MUSCLE FIBERS CONDUCTION VELOCITY IS MAINLY AFFECTED BY FORCE INTENSITY THAN CONTRACTION SPEED DURING ISOKINETIC EXERCISE
Ciarla G, Gizzi L, Ronca M, Bazzucchi I

T07.P6. TENNIS PLAYERS SHOW A LOWER COACTIVATION OF THE ELBOW ANTAGONIST MUSCLES DURING ISOKINETIC EXERCISES
Bazzucchi I, Riccio ME, Menotti F, Sacchetti M, Felici F

T07.P7. THE CONTROL OF UPSIDE-DOWN STANDING POSTURE IN SKILLED AND NON-SKILLED SUBJECTS
Sbriccoli P, Brienza A, Masci I, De Vito G

T07.P8. STUDY ELECTROMYOGRAPHIC OF MUSCLES DURING THE MANUAL PREHENSION OF DIFFERENTS OBJECTS
Amorim LJ, Amorim CF, Kelencs CA, Pereira LC, Macau HN, Nascimento LL, Veronezi JJR, Zângaro RA, Pacheco MTT

T07.P9. STUDY OF ELECTROMYOGRAPHIC ACTIVITY OF THE MASSETER MUSCLE IN SLEEP BRUXERS
Amorim CF, Ferreira LMA, Amorim IJ, Santos C, Oliveira LVF

T07.P10. ELECTROMYOGRAPHIC ANALYSIS OF ABDOMINAL MUSCLE IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS
Amorim CF, Serrão NF, Amorim L.J, Veronesi JJ Ronaldo, Macau HN, Chavantes MC

T07.P11. STUDY OF INSPIRATORY CAPACITY IN COPD THROUGH SURFACE ELECTROMYOGRAPHY
Amorim CF, Serrão NF, Amorim L.J, Veronesi JJ Ronaldo, Macau HN, Chavantes MC

T07.P12. EVALUATION OF ELECTROMYOGRAPHIC ACTIVITIES OF MASSETER AND TEMPORAL MUSCLES IN INDIVIDUALS WITH TEMPOROMANDIBULAR DISFUNCTION
Amorim CF, Amorim LJ, Kelencs CA, Oliveira LVF, Macau HN, Nascimento LL, Veronezi JJR, Pacheco MTT, Zângaro RA

T07.P13. AMOUNT OF RECIPROCAL IA INHIBITION IN ISOKINETICS MOVEMENT
Miwa M, Makabe H, Ihashi K

T07.P14. MODULATION OF SOLEUS H-REFLEX AND SPINAL INHIBITORY CONTROL SYSTEMS DURING IMPOSED SINUSOIDAL HIP MOVEMENTS IN HUMAN SPINAL CORD INJURY
Chaudhuri D, Knikou M, Schmit BD, Kay E

T07.P15. CORTICOSPINAL EXCITABILITY CHANGES DURING LENGTHENING BUT NOT SHORTENING CONTRACTIONS AFTER TRAINING
Sekiguchi H, Kohno Y, Yamazaki N, Akai M, Nakajima Y, Nakazawa K

T07.P16. CORTICAL REGULATION OF ISOMETRIC FORCE - CORTICOMUSCULAR COHERENCE ANALYSIS -
Ushiba J, Katsu M, Tsutsumi N, Masakado Y, Tomita Y

T07.P17. A SIMPLE VALIDATION OF CO-CONTRACTION INDICES
Ervilha UF, Duarte M, Arendt-Nielsen L, Graven-Nielsen T

T07.P18. DIFFERENTS PATTERNS OF RECRUITMENT IN ECCENTRIC AND CONCENTRIC CONTRACTIONS IN MULTIFIDUS LUMBORUM DURING FLEXION-RELAXATION TEST
Vásquez G, Silvestre R

T07.P19. NEURONAL CONTROL OF UPRIGHT POSTURE ON ROCKING-PLATFORM
Tsutsumi N, Ushiba J, Masakado Y, Tomita Y

T07.P20. ANGLE- AND VELOCITY-SPECIFIC ALTERATIONS IN TORQUE AND SEMG ACTIVITY OF THE QUADRICEPS AND HAMSTRINGS DURING ISOKINETIC EXTENSION-FLEXION MOVEMENTS
Croce RV, Miller JP, Horvat M

T07.P21. EVALUATION OF THE ADDUCTOR POLLICIS MUSCLE OF ELDERLY PATIENTS USING A MODIFIED HANDLE OF TOOTHBRUSH
Mattos MGC, Franco RL, Vitti M, Ribeiro RF, Semprini M, Lopes RA

T07.P22. ROLE OF BOTH INTERACTION TORQUE AND MUSCLE TORQUE IN SQUATTING
Fujisawa H, Yamazaki H, Nagasaki H

T07.P23. CHANGES OF CORTICOMUSCULAR COHERENCE DURING MUSCLE FATIGUE
Katsu M, Ushiba J, Masakado Y, Tomita Y

T07.P24. LEARNING AND CONTROL MODEL OF THE ARM FOR MAINTAINING POSITIONS WITH DIFFERENT WEIGHTS ON HAND
Kim KS, Kambara H, Kim DO, Shin Duk, KoikeY

T07.P25. IN-PHASE MUSCLE ACTIVATION MAKES IT EASIER TO MOVE IPSILATERAL HAND AND FOOT IN OPPOSITE DIRECTIONS
Muraoka T, Obu T, Kanosue K

Motor Units (T09)

T09.P1. MOTOR UNIT CONDUCTION VELOCITY DURING SUSTAINED CONTRACTION OF THE VASTUS MEDIALIS MUSCLE
Hedayatpour N, Arendt-Nielsen L, Farina D

T09.P2. INTERNET-BASED RESEARCH RESOURCE FOR EMG DECOMPOSITION: SOFTWARE, DATA, AND MORE
McGill KC, Clancy EA

T09.P3. ELECTROMYOGRAPHY ACTIVITY ANALYSES IN THE ORTHOSTATIC POSTURE BEFORE AND AFTER CRYOTHERAPY APPLICATIONS
Pasini Neto H, Forti F, Guirro RRJ

T09.P4. ANALYSIS OF MOTOR UNIT POTENTIALS IN HEALTHY SUBJECTS
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T09.P5. THE EFFECT OF GENDER AND AGE ON MOTOR UNIT NUMBER ESTIMATION IN NORMAL POPULATION
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T09.P6. VARIABILITY OF SINGLE MOTOR UNIT ACTIVITY DURING FATIGUING SUSTAINED CONTRACTIONS
Sadoyama T, Sugahara T, Kamijo M

T09.P7. MOTOR UNIT SYNCHRONIZATION IN PREVIOUSLY FATIGUED MUSCLE
Olsen HB, Søgaard K

T09.P8. INFLUENCE OF MENTAL STRESS ON SINGLE MOTOR UNIT ACTIVITY
Kamijo M, Yanagisawa K, Sugahara T, Sadoyama T

T09.P9. SURFACE ELECTROMYOGRAPHIC SPIKE FREQUENCY AND MOTOR UNIT FIRING RATES AT DIFFERENT LEVELS OF MAXIMUM CONTRACTION
Gabriel D, Christie A, Inglis GJ, Kamen G

Muscle Fatigue (T10)

T10.P1. COMPARISON OF THE LEVEL OF FATIGUE BETWEEN DIFFERENT MUSCLE GROUPS USING EMG SPECTRAL ESTIMATES AND THE BORG CR-10 SCALE
Larivière C, Da Silva RA, Arsenault AB, Nadeau S, Plamondon A

T10.P2. ELECTROMYOGRAPHIC STUDY IN ERECTOR SPINAE, RECTUS ABDOMINIS, GLUTAEOUS MAXIMUS AND RECTUS FEMURIS MUSCLES, IN STANDING AND STATIC POSTURE
Sgobbi CRF, Bérzin F

T10.P3. ELECTROMYOGRAPHY EVALUATION OF OCCLUSAL SPLINT INFLUENCE ON ORBICULARIS ORIS IN DENTURE-WEARING SUBJECTS WITH TEMPOROMANDIBULAR DYSFUNCTION
Fonseca-Silva AS, Semeguini TA, Bérzin F

T10.P4. CLINICAL AND ELETROMYOGRAPHIC EVALUATION OF THE PLANAS APPLIANCE IN PATIENTS WITH TEMPORO-MANDIBULAR DYSFUNCTION
Faria RJA, Caria PHF, Sgobbi CRF, Negão Filho RF

T10.P5. SEMG AND FUNCTIONAL MAXILLARY ORTHOPEDICS: MUSCLE REST RECORD BEFORE AND AFTER 8 MINUTES OF APPLIANCE USE
Sakai E, Bérzin F, Pedroni CR

T10.P6. SEMG AND FUNCTIONAL MAXILLARY ORTHOPEDICS: RESULTS FOR DIAGNOSIS
Sakai E, Bérzin F, Nagae MH

T10.P7. SEMG AND FUNCTIONAL MAXILLARY ORTHOPEDICS: THE RESULTS AFTER OBTAINING DETERMINED AREA (D.A.) DENTAL CONTACT
Sakai E, Bérzin F

T10.P8. THE RELATIONSHIP BETWEEN STERNOCLEIDOMASTOID ACTIVITY AND NECK DISABILITY INDEX IN CHRONIC PAIN PARTICIPANTS (PILOT STUDY)
Curtis SA, Burridge JH, De Stefano A

T10.P9. ANALYSIS OF ELECTROMYOGRAPHIC FATIGUE THRESHOLD AT DIFFERENT RESISTED ELBOW FLEXION EXERCISES
Gonçalves M, Anderson de Souza CO

T10.P10. EFFECT OF A SHORT PERIOD ENDURANCE TRAINING ON THE ELECTROMYOGRAPHIC FATIGUE THRESHOLD
Cardozo AC, Gonçalves M

T10.P11. EVALUATION OF MUSCLE FATIGUE DURING SKIING BY EMG SIGNALS SELECTED WITH KNEE JOINT ANGLES
Ushiyama Y, Kiryu T, Chigira T, Murayama T

T10.P12. ELECTROMYOGRAPHY OF THE RESPIRATORY MUSCLES AND A PHERIPERAL MUSCLE DURING AN ERGOMECTRIC TEST
Costa D, Riedi C, Tesch C

T10.P13. ELECTROMYOGRAPHIC EVALUATION OF CARRIERS PATIENTS OF TEMPOROMANDIBULAR DISORDER SUBMITTED TO INTERDISCIPLINAR TREATMENT - CLINICAL CASES
Ferraz MJPC, Barbosa JRA, Bérzin MGR, Alves LMC, Bérzin F

T10.P14. RADIOGRAPHIC STUDY OF THE CRANIOMANDIBULAR BIOMECHANICS QUANTIFIED BY THE SURFACE ELECTROMYOGRAPHY OF MASTICATORY MUSCLES- REPORT CASES
Coelho-Ferraz MJP, Berzin F, Colletes Alves LM, Berzin MGR

T10.P15. COMPARISON OF WAVELET AND FOURIER ANALYSES OF EMG SIGNALS TO ASSESS MUSCLE FATIGUE DURING DYNAMIC CONTRACTIONS
Da Silva RA, Larivière C, Arsenault AB, Nadeau S, Plamondon A

T10.P16. IS THERE ANY CHANGE ON SHOULDER AND SCAPULA PROPRIOCEPTION AFTER FATIGUE OF THE INTERNAL ROTATORS?
Guo L-Y, Yang C-H, Wu W-L, Lin H-T

T10.P17. EMERGING STRATEGIES FOR FATIGUE ESTIMATION DURING DYNAMIC MUSCLE CONTRACTIONS
Rogers DR, MacIsaac DT

T10.P18. ELECTROMYOGRAPHIC RESPONSE OF THE STERNOCLEIDOMASTOID AND TRAPEZIUS MUSCLES IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS
Ries LGK, Bérzin F

T10.P19. MUSCULAR ASSESSMENT OF THE TRAINING TECHNIQUES OF THE SUPERIOR LIMBS IN THE PULMONARY REHABILITATION PROGRAM: DIAGONAL MOVEMENT VERSUS ROWING
Corrêa JCF, Oliveira AN, Ribeiro PMG, Júnior RNM, Fernandes AO, Peres JA, Bérzin F

T10.P20. EMG TOPOGRAPHY DURING ISOMETRIC, FATIGUING CONTRACTION OF THE UPPER TRAPEZIUS
Leclerc F, Madeleine P, Farina D

Neurophysiology (T11)

T11.P01. RELIABILITY OF DIFFERENT METHODS OF DETERMINING THE LATENCY OF A MOTOR EVOKED POTENTIAL AT THE INFRASPINATOUS
Sheehy LM, McLean L

T11.P02. EFFECTS OF GENDER AND AGE ON AXONAL EXCITABILITY
Koc F

T11.P03. THE EFFECT OF AGE ON CHEWING
Galo R, Vitti M, Mattos MGC, Santos CM, Hallak JEC, Regalo SCH

T11.P04. PROPRIOCEPTIVE FEEDBACK CONTRIBUTES TO CORTICAL MAGNETIC FIELDS RELATED TO FINGER EXTENSION
Onishi H, Soma T, Oyama M, Oishi M, Fuijmoto A, Kameyama S, Kurokawa Y

T11.P05. CORRELATION AMONG THE SITTING BEARING WEIGHT AND SENSORIAL ALTERATION IN THE GLUTEAL REGION IN HEMIPLEGIC/HEMIPARETIC PATIENTS
Torriani C, Queiroz SS, Cyrillo FN, Fernandes S, Padoan BB, Correa LCB, Coelho CG, Gama DM, Pereira DP, Relvas FR

T11.P06. COMPARATIVE ASSESMENT OF THE BALANCE IN CEREBELAR DISEASE AND POST STROKE PATIENTS
Torriani C, Queiroz SS, Cyrillo FN, Sakakura MT, Zicati M, Volpini AF

T11.P07. SOMATOSENSORY EVOKED POTENTIALS OF SUBACUTE MYELO-OPTICO-NEUROPATHY IN RELATION TO SPINAL CORD CONDUCTION VELOCITIES
Matsumoto A, Tajima T, Sasaki H

T11.P08. MECHANICAL AND SEMG MANIFESTATIONS OF FATIGUE IN SUBJECTS WITH ANOREXIA NERVOSA
Melchiorri G, Rainoldi A

T11.P09. INSTRUMENTED STRETCH REFLEXES OF FLEXOR CARPI RADIALIS AND FLEXOR CARPI ULNARIS MUSCLE
de Groot JH, Jägers D, Meskers CGM, Schouten AC, de Vlugt E, Arendzen JH

T11.P10. PHASE AND FREQUENCY COORDINATION REPAIR IN THE INJURED OR MALFUNCTIONING HUMAN CNS BY COORDINATION DYNAMICS THERAPY
Schalow G

h 11.45-12.45 ORAL PRESENTATIONS

Sala 500 **Neurophysiology (*Chairs: Moritani T, Lateva Z*)**

A NOVEL APPROACH FOR THE ESTIMATION OF MOTOR NERVE CONDUCTION BLOCK
Mesin L, Cocito D

CHANGE OF H WAVE AND MEP DURING PEDALLING BY ONE LEG
Seki K, Mitsuhasi K, Akamatsu C, Handa Y

EFFECTS OF HYPOXIA ON NEUROMUSCULAR ACTIVATION
Szubski C, Burtscher M, Löscher W

CORTICAL RECIPROCAL INHIBITION IS REDUCED IN OLD HUMANS
Hortobágyi T, Olmo del FM, Rothwell JC

Sala Londra **Motor Control (*Chairs: McGill K, Falla D*)**

TRUNK MUSCLE RESPONSES TO SUDDENLY APPLIED LOADS BEFORE AND AFTER A PROLONGED PERIOD OF STANDING
Gregory DE, Brown SHM, Callaghan JP

VOLUNTARY ACTIVATION OF TRAPEZIUS DURING UNILATERAL AND BILATERAL VOLUNTARY CONTRACTION
Søgaard K, Olsen HB, Sjøgaard G, Taylor JL

DIFFERENTIAL ACTIVITY OF DEEP AND SUPERFICIAL THORACIC PARASPINAL MUSCLES DURING VOLUNTARY ARM MOVEMENTS
Lee LJ, Coppieters MW, Hodges P W

A STUDY OF MOTOR CONTROL FOR LOAD ON TASK USING ELETROMYOGRAPHIC SIGNALS
Shin D, Kim KS, Kim D, Koike Y

Sala Madrid **Gait and movement analysis (*Chairs: Frigo C, Benedetti MG*)**

EFFECT OF ELECTRODE LOCATION ON EMG SIGNAL ENVELOPE IN LEG MUSCLES DURING GAIT
Campanini I, Merlo A, Degola P, Merletti R, Vezzosi G, Farina D

CONTROL OF HEAD STABILITY DURING GAIT INITIATION IN YOUNG AND OLDER WOMEN
Laudani L, Casabona A, Perciavalle V, Macaluso A

MUSCLE ACTIVATION PATTERNS DURING GAIT IN CHILDREN
Caffaratto JP, Gaffuri A, Imazio P, Knaflitz M, Nascimbeni A

h 12.45-14.00 LUNCH

h 14.00-15.00

Sala 500 KEYNOTE LECTURE 3: Paul Enck
Age, incontinence symptoms, and mode of delivery affect anal sphincter EMG asymmetry

h 15.15-16.15 ORAL PRESENTATIONS

Sala 500 **Incontinence and pelvic floor EMG (*Chairs: Enk P, Merletti R*)**

ABDOMINAL AND PELVIC FLOOR MUSCLE ACTIVATION DURING COUGHING IN WOMEN WITH AND WITHOUT URINARY INCONTINENCE
Gonçalves F, Brown C, McLean L

DETECTION OF NEUROGENIC DETRUSOR OVERACTIVITY BY ANALYSIS OF URETHRAL SPHINCTER EMG
Hansen J, Borau A, Rodríguez A, Vidal J, Sinkjær T, Rijkhoff NJM

A BIOMECHANICAL MODEL OF INTRAVAGINAL PRESSURE GENERATION COMPARING CONTINENT AND STRESS INCONTINENT WOMEN
Madill SJ, McLean L

POSTURAL RESPONSE OF THE PELVIC FLOOR AND ABDOMINAL MUSCLES IN WOMEN WITH AND WITHOUT INCONTENCE
Smith MD, Coppieters MW, Hodges P W

Sala Londra **EMG Modeling (*Chairs: Stegeman D, Farina D*)**

SIMULATION OF MOTOR UNIT ACTION POTENTIALS THROUGH A POINT DISTRIBUTION MODEL
Andrade AO, Nasuto SJ, Kyberd P

A MODEL OF ELECTRICAL STIMULATION
Mesin L

ESTIMATING THE ACCURACY OF EMG DECOMPOSITION RESULTS
McGill KC, Marateb HR

SIMULATIONS OF SURFACE ELECTROMYOGRAFIC SIGNALS IN A DISTRIBUTED ENVIRONMENT (GRID)
Gazzoni M, Lo Conte L, Merletti R

Sala Madrid **Gait and movement analysis (*Chairs: Bonato P, Campanini I*)**

JOINT FUNCTION CHANGES IN HEMIPARETIC GAIT AFTER VISUAL EMG BIOFEEDBACK TRAINING
Aiello E, Gates DH, Patritti BL, Cairns KD, Meister M, Clancy EA, Della Croce U, Bonato P

HUMAN SILHOUETTE TRACKING BY A NEURAL APPROACH: NEURAL SNAKES
Goffredo M, Conforto S, Schmid M, D'Alessio T

ROBOT BASED METHOD FOR FUNCTIONAL TESTING OF UPPER EXTREMITY MOVEMENT PERFORMANCE
Popovic N, Schmitz-Rode T, Rau G, Disselhorst-Klug C

FUNCTIONAL AND BIOMECHANICAL ASSESSMENT IN BIOLOGICAL RECONSTRUCTION OF FEMUR IN CHILDREN WITH BONE SARCOMA
Berti L, Benedetti MG, Mariani G, Manfrini M, Giannini S

h 16.15-17.15 COFFE BREAK and **POSTER SESSIONS: Physical Medicine and Rehabilitation (T12), Rehabilitation Engineering (T14), Sensor and wearable/ambulatory technology and applications (T15), Virtual and augmented reality in rehabilitation (T19).**

Physical Medicine and Rehabilitation (T12)

T12.P01. CORRELATION BETWEEN ELECTROMYOGRAPHIC AND ULTRASONOGRAPHIC DATA OF THE MASSETER MUSCLE IN CHILDREN
Felício CM, Santos T, Thomazinho A, Regalo SCH, Vitti M, Elias Jr J, Vasconcelos PB

T12.P02. SURFACE EMG OF THE MASSETERS AND ANTERIOR TEMPORALIS MUSCLES AND CHEWING CYCLES IN CHILDREN WITH DEEPBITE
Piancino MG, Farina D, Bombara M, Femia G, Talpone F, Bracco P

T12.P03. SPEECH FLUENCY PROFILE AND ELECTROMIOGRAPHIC ANALYSIS OF MASSETER AND TEMPORAL MUSCLES
Felício CM, Freitas RLG, Regalo SCH, Vitti M, Ferrioli BHMV, Ferreira CLP

T12.P04. MORPHOFUNCTIONAL COMPARISON OF CHILDREN WITH DENTO-ALVEOLAR AND SKELETAL ANTERIOR OPEN BITE
Felício CM, Santos T, Thomazinho A, Elias Jr J, Regalo SCH, Vitti M, Vasconcelos PB

T12.P05. DISORDERS OF MASTICATORY MUSCLES BEFORE AND AFTER POSTERIOR CROSS BITE TREATMENT - EMG ANALYSIS
De-Rossi M, Gavião MBD, Stuani MBS, Vitti M, De-Rossi A, Hallak JEC, Semprini M, Regalo SCH

T12.P06. RELATION BETWEEN RDC/TMD AND ELECTROMYOGRAPHY OF WOMEN WITH AND WITHOUT TEMPOROMANDIBULAR DYSFUNCTION
Tosato JP, Bérzin F, Caria PHF

T12.P07. ELECTROMYOGRAPHIC ANALYSIS OF THE MASTICATORY MUSCLES IN PATIENTES WITH TEMPOROMANDIBULAR DISORDER DURING CHEWING
Rodrigues Pedroni C

T12.P08. ELECTROMYOGRAPHIC ANALYSIS OF MASTICATORY MUSCLES OF ORTODONTICALLY TREATED PATIENTS, BEFORE AND AFTER OCCLUSAL ADJUSTMENT
Facioli RHM, Vitti M, Semprini M, Santos CM, Hallak JEC, Bataglion C, Siéssere S, Souza LG, Regalo SCH

T12.P09. CHANGES IN MASTICATORY MUSCLES ACTIVITY ASSOCIATED WITH EAGLE'S SYNDROME
Regalo S, Vitti M, Semprini M, Santos CM, Hallak JEC, De-Rossi M, Souza LG, Watanabe PCA, Rosa LB, Siéssere S

T12.P10. THE CORRELATION BETWEEN ELECTROMYOGRAPHIC ACTIVITY AND BITING STRENGTH IN BRAZILIAN INDIANS (XINGU VILLAGES)
Mathias V, Santos CM, Mestriner Jr W, Vasconcelos PB, Semprini M, Hallak JEC, Dias FJ, Regalo CA, Pagnano VO, Regalo SCH

T12.P11. ELECTROMYOGRAPHIC COMPARISON OF MASTICATORY MUSCULATURE ACTIVITY BETWEEN BRAZILIAN INDIGENOUS MEN AND WOMEN AND CIVILIZED INDIVIDUALS
Regalo SCH, Mathias V, Mestriner Jr W, Vasconcelos PB, Semprini M, Hallak JEC, Ribeiro LR, Regalo CA, Souza LG, Santos CM

T12.P12. THE EFFECT OF BRAZILIAN INDIANS' HABITS ON THE ACTIVITY OF STOMATOGNATHIC SYSTEM MUSCLES - ELECTROMYOGRAPHIC ANALYSIS
Santos CM, Mathias V, Mestriner Jr W, Vasconcelos PB, Semprini M, Hallak JEC, Dias FJ, Regalo CA, Siessere S, Regalo SCH

T12.P13. EFFECT OF THE TREATMENT USING TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION, IN TEMPOROMANDIBULAR DYSFUNCTION PATIENTS
Gonçalves R, Rodrigues D, Rodrigues Pedroni C, Bérzin F

T12.P14. QUALITY OF REPORTING ELECTROMYOGRAPHY IN MASTICATORY MUSCLES - A SYSTEMATIC REVIEW
Armijo-Olivo S, Gadotti IC, Kornerup I, Lagravère M, Flores-Mir C

T12.P15. ELECTROMYOGRAPHIC ACTIVITY OF THE MASTICATORY AND CERVICAL MUSCLES DURING RESISTED JAW OPENING MOVEMENT
Armijo-Olivo S, Gadotti IC, Magee D

T12.P16. EFFECT OF TREATMENT OF DENTOFACIAL DEFORMITIES ON THE ELECTROMYOGRAPHIC ACTIVITY OF MASTICATORY MUSCLES
Trawitzki LVV, Dantas RO, Mello-Filho FV, Marques W Jr

T12.P17. ELECTROMYOGRAPHIC EVALUATION OF MUSCLES IN EDENTULOUS PATIENTS USING COMPLETE DENTURES WITH SLIDING PLATES
Vitti M, Nóbilo K, Zuccolotto MMC, Regalo SCH, Bataglion C

T12.P18. ELETROMYOGRAPHIC ACTIVITY OF THE ORBICULAR MUSCLE OF THE MOUTH STUTTERERS AND FLUENT SPEAKERS
Felício CM, Freitas RLG, Regalo SCH, Vitti M, Ferrioli BHMV

T12.P19. THE USE OF EIGHT-POINT BINDING AS A PHYSIOTHERAPEUTIC RESOURCE FOR THE MUSCULAR DORSIFLEXORES´S RECRUITMENT IN GAIT
Torriani C, Queiroz S, Cyrillo FN, Roxo R, Macari R, Domingos V

T12.P20. COMPARATIVE ANALYSES OF THE PAIN AND THE EMG ACTIVITY OF TRAPEZIUM AFTER TENS AND POSITIONAL RELEASE THERAPY
Cyrillo FN, Luongo AC, Torriani C, de Souza Pinto S

T12.P21. THE DIFFERENCE OF ALIGNMENT OF LUMBAR VERTEBRAE AND LUMBAR RANGE OF MOTION IN FOUR POSTURES
Nakamata O, Furukawa Y, Hosoda M, Kamio H, Kaneko S

T12.P22. EVALUATION OF THE REDUCTION OF PAIN IN DESCENDING FIBERS OF THE TRAPEZIUM, AFTER THE APPLICATION OF PRT (POSITIONAL RELEASE THERAPY) TECHNIQUE
Cyrillo FN, Sencovicci L, Sartori LF, Torriani C, Debessa C

T12.P23. INFLUENCE OF THE APPLICATION OF TENS ON THE ELECTROMYOGRAPHIC ACTIVITY OF CERVICAL MUSCLES IN DYSPHONIC PATIENTS
Guirro RRJ, Berni KCS, Distefano G, Santos FL, Forti F, Rodrigues D, Silvério KCA

T12.P24. EFFECTS OF AMBULATORY AIDS ON POSTURAL STABILITY
Soma T, Onishi H, Oyama M, Ehara Y, Kurokawa Y

T12.P25. ANALYSIS OF POSTURAL REACTION OF SITTING BALANCE USING BALANCE BOARD
Morishita M, Amimoto K, Yamada C, Takakura Y, Kusano S

T12.P26. DEVELOPMENT OF THE COMPACT MRI ENABLED FOOT IMAGING IN STANDING POSTURE
Takayanagi K, Hayashi T, Monma M, Fujii H, Takeda H, Ohyama Y, Hosoda M, Kubota A

T12.P27. INFLUENCES OF VISUAL VERTICALITY ON POSTURAL CONTROL OF HEMIPLEGIC PATIENTS
Amimoto K, Ohkuma O, Yanagisawa K

T12.P28. ARM, NECK AND TRUNK COORDINATION DURING EATING ACTION IN PATIENTS WITH RIGHT HEMIPLEGIA
Matsubara A, Murakami T, Kurumadani H, Sawada T

T12.P29. EFFECT OF FACILITATION OF BALANCE ABILITY USING BALANCE BOARD IN HEMIPLEGIC PATIENTS AFTER STROKE
Matsuda T, Amimoto K, Nozaki H, Arai Y, Ichiki S, Ichiba M, Igarashi H, Nihei A

T12.P30. ELICITING MUSCULAR ACTIVITY IN SPINAL CORD INJURED PERSONS EXPOSED TO LEG VIBRATION
Kakebeeke TH, Hofer PJ

T12.P31. CORPORAL OSCILLATION DURING STATIC BIPED POSTURE IN CHILDREN WITH CEREBRAL PALSY
Bigongiari A, Martinelli JL, Franco RC, Corrêa JCF

T12.P32. PERONEOUS LONGUS MUSCLE REACTION TIME ANALYSIS DURING SUDDEN INVERSION TEST OF THE ANKLE THROUGH SURFACE ELECTROMYOGRAPHY: SYSTEMATIC REVIEW
Cardoso JR, Toyohara MT, Chagas LMPM, Oliveira BIR

T12.P33. ESTABLISHMENT OF MOVEMENT INTENSITY AND THE OPTIMUM FREQUENCY OF MOVEMENT BY USING 1 REPETITION MAXIMUM
Ibata Y, Saotome H, Machino M, Kubota Y, Takei H

T12.P34. EFFECTS OF FATIGUE ON VOLITIONAL AND MAGNETICALLY-EVOKED KNEE FLEXOR ELECTROMECHANICAL DELAY OF MALES AND FEMALES
Minshull C, Gleeson N, Walters-Edwards M, Rees D

T12.P35. ELECTROMYOGRAPHIC COMPARISON BETWEEN INDIVIDUALS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND WITHOUT INJURIES DURING PERTURBATION EXERCISES
Cardoso JR, Santos ABAN, Pereira HM, Rabello LN, Jorge DA, Nowotny AH

T12.P36. THE RELIABILITY OF MAXIMUM ISOMETRIC NECK FLEXION AND EXTENSION STRENGTH IN HEALTHY MEN AND WOMEN
Vikne H, Vøllestad N

T12.P37. SURFACE EMG VARIABLE ESTIMATES DURING UPPER LIMB DYNAMIC CONTRACTIONS. A COMPARISON BETWEEN AIR AND UNDERWATER ENVIRONMENTS
Veneziano WH, De Vietro M, Rocha AF, Gonçalves CA, Rainoldi A

T12.P38. INVESTIGATION OF THE ADEQUATENESS OF JERK AS A MEASURE OF HAPTIC SENSING ABILITY FOR UPPER LIMB BY A HAPTIC DEVICE SYSTEM
Ikeda Y, Inoue K, Terada T, Ito Y, Nitta O, Takei H, Suzuki T, Takahashi Y, Watanabe S, Kaneko S

T12.P39. UPPER LIMB TREMOR FOR SHOULDER PATIENTS AND HEALTHY PERSONS
Sakamoto K, Kurokawa T, Yamaji T, Makabe H, Mito K, Takanokura M, Kaneko K

T12.P40. SHORT-TERM EFFECTS OF RESISTANCE TRAINING USING ELASTIC BANDS IN THE ELDERLY
Yamada T, Hosoda M

T12.P41. ANALYSIS OF HEART RATE RECOVERY TIME AT EXERCISE TESTING BELOW THE ANAEROBIC THRESHOLD LEVEL
Furukawa Y, Nakamata O, Nakajima I, Ikeda Y, Takei H, Hosoda M, Ikeda M, Yanagisawa K, Kaneko S

Rehabilitation Engineering (T14)

T14.P01. INVESTIGATION OF THE EFFECT OF WEAK PULSED MAGNETIC STIMULATION FOR MUSCLE FATIGUE
Yunokuchi K, Nuruki A, Tsujimura S, Fuchino S, Furuichi H

T14.P02. BASIC RESEARCH ON TRANSFEMORAL PROSTHESE USING SURFACE ELECTROMYOGRAPHY
Chen L, Yang P, Guo X, Zhang G, Li L

T14.P03. STUDY OF TERRAINS IDENTIFICATION BY EXTRACTING FEATURE VECTOR OF SEMG BASED ON LVQ NEURAL NETWORK
Guo X, Yang P, Liu H, Chen L

T14.P04. CLASSIFICATION OF HIGH DENSITY SURFACE EMG SIGNALS DEVELOPED BY TARGETED MUSCLE REINNERVATION
Zhou P, Englehart KB, Lowery MM, Kuiken TA

T14.P05. ANALYTICAL MODELIZATION OF PLANAR MONOARTICULAR MOVEMENTS FOR THE DETERMINATION OF THE RESISTIVE COEFFICIENT IN MUSCLE STRENGTH EXERCISE
Ranavolo A, Iovino M, Cacchio A, Don R, Frascarelli M, Pepino A, Santilli V

T14.P06. FIRST EXPERIENCE OF MECFES FOR ASSISTING TETRAPARETIC HANDS IN ACTIVITIES OF DAILY LIVING
Thorsen R, Binda L, Occhi E, Ferrarin M

T14.P07. A NEW CLINICAL TOOL FOR THE ASSESSMENT OF THE HAND FUNCTIONALITY
Giansanti D, Morelli S, Giacomozzi C, Maccioni G, Macellari V

T14.P08. FES ROWING AFTER SPINAL CORD INJURY
Poulton A, Andrews B, Hettinga D, Paton R

T14.P09. DEVELOPMENT OF COOPERATIVE WORK SYSTEM DRIVEN BY ULTRASONIC MOTOR USING ELECTROMYOGRAPHIC SIGNALS
Kim D-O, Watanabe M, Kim K-S, Shin D, Koike Y

Sensor and wearable/ambulatory technology and applications (T15)

T15.P01. LIDWINE - A EUROPEAN PROJECT ON PREVENTION AND TREATMENT OF BEDSORES
Van Langenhove L, Hertleer C

T15.P02. A WIRELESS INTELLIGENT SENSOR FOR REAL TIME ADL MONITORING
Caselli P, Bibbo D, Schmid M, D'Alessio T

T15.P03. TRIGGERLESS DETERMINATION OF BALLISTOCARDIOGRAPHIC WAVEFORMS
Florestal JR, Bura M, Schmid M, Conforto S, Mathieu PA, D'Alessio T

T15.P04. ACTIVITY CLASSIFICATION USING TIME-DEPENDENT NEURAL NETWORKS
Chang S, Nawab H, Roy SH, De Luca CJ

T15.P05. ADJUSTING DBS SETTINGS TO OPTIMIZE PARKINSON'S CONTROL THERAPY
Hester T, Hughes R, Sherrill DM, Patel S, Huggins N, Flaherty A, Standaert D, Bonato P

T15.P06. MOTION MONITORING WITH WEARABLE SENSORS
Hanser F, Szubski C, Lukowicz P

T15.P07. WEARABLE FORCE SENSORS FOR DETECTING MUSCLE ACTIVITY AND MUSCLE FATIGUE
Szubski C, Hanser F, Lukowicz P

Virtual and augmented reality in rehabilitation (T19)

T19.P01. EFFECTS ON BALANCE AND STRENGTH FOLLOWING RESISTANCE EXERCISE PERFORMED ON AN UNSTABLE SURFACE IN A NINETY DEGREE TILTED ENVIRONMENT
Zemkova E, Dwyer A, Chow A, Oddsson LIE

T19.P02. EFFECT OF VISUAL MOTION ON BALANCE DURING A DUAL TASK PERFORMED WITHIN A DYNAMIC ENVIRONMENT
Dvorkin AY, Kenyon RV, Streepey JW, Keshner EA

h 17.15-18.15 ORAL PRESENTATIONS

Sala 500 **Physical Medicine and Rehabilitation (*Chairs: Arsenault B, Falla D*)**

SEMG UTILIZATION IN THE PHYSICAL MEDICINE AND THERAPY CONTEXT
Sella GE

TIME COURSE OF MUSCULAR, CONNECTIVE TISSUE AND NEURAL ADAPTATIONS TO UNILATERAL LOWER-LIMB UNLOADING
Narici MV, De Boer MD, Seynnes OR, Maganaris CN

EFFECT OF ABDOMINAL BRACING AND ABDOMINAL HOLLOWING MANEUVERS ON THE CONTROL OF SPINE STABILITY
Vera-Garcia FJ, Elvira JLL, Brown SHM, McGill SM

MODULATION OF CORTICOSPINAL EXCITABILITY FOLLOWING MOTO IMAGERY TRAINING OF KNEE EXTENSION
Tremblay LE, Abdulla K, Lessard J, Maheu P, Malette J, Rajotte E

Sala Londra **Motor Control (*Chairs: Sjogaard G, Zwarts M*)**

IS PROPRIOCEPTION REDUCED IN SUBJECTS WITH SYMPTOMATIC ELBOWS?
Juul-Kristensen B, Lund H, Hansen K, Christensen H, Danneskiold-Samsøe B, Bliddal H

THE CONTRIBUTION OF THE WRIST AND ELBOW JOINTS DURING SINGLE FINGER TAPPING
Dennerlein J, Kingma I, Visser B, van Dieën J

NEURAL CONTROLLER FOR BALLISTIC MOVEMENTS OF THE UPPER ARM
Bernabucci I, Speranza A, Conforto S, Schmid M, D'Alessio T

PREDICTION OF ELBOW MECHANICAL IMPEDANCE WITH SURFACE EMG
Bourret PE, Rancourt D, Martel S, Clancy EA

Sala Madrid **Posture (*Chairs: Carollo J, Benvenuti F*)**

POSTURAL RESPONSES TO PROPRIOCEPTIVE STIMULATION: DEPENDENCE ON STIMULUS DURATION
Rocchi L, Hlavacka F, Chiari L, Cappello A

GAIT INITIATION DIFFERS BETWEEN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY AND AGE-MATCHED CONTROLS
Carollo JJ, Dezman ZD, Konieczny A

RELATIONSHIP BETWEEN DYNAMIC BALANCE AND STOOPING POSTURE DURING GAIT IN ELDERLY PEOPLE
Sato H, Shinohara A, Nakamura A, Kimono A

FLEXED POSTURE IN ELDERLY: CLINICAL AND INSTRUMENTAL ASSESSMENT AND EFFECTS OF PHYSICAL ACTIVITY PROGRAMS
Benedetti MG, Berti L, Presti C, Cremonini K, Giannini S

h 18.15-18.30

Sala 500 Presentation of the next ISEK Congress site

h 21.00 Gala Dinner at the Automotive Museum of the City of Torino

SATURDAY, JULY 1, 2006

h 08.00-09.00

Sala 500 KEYNOTE LECTURE 4: Winfried Mayr
Novel emerging applications in functional electrical stimulation

h 09.15-10.45 ORAL PRESENTATIONS

Sala 500 **Physical Medicine and Rehabilitation (*Chairs: Sella G, Mayr W*)**

CORTICOMOTOR MODULATIONS FOLLOWING INDUCED AND VOLUNTARY KNEE EXTENSION EXERCICES
Tardif C, Tremblay LE, Chamberland P, Boudreau A, Tremblay F

KNEE AND ANKLE EXTENSORS COACTIVATION DURING GAIT IS RELATED TO DEFICIENT SPINAL MODULATION IN HEMIPARESIS
Dyer JO, Maupas E, Forget R

THE NOT INSIGNIFICANT ROLE OF BWS TREADMILL TRAINING IN IMPROVING COORDINATION IN LOWER MOTONEURON PATIENTS
Benjuya N

DIFFERENCES IN MUSCLE ACTIVATION PATTERNS DURING WALKING BETWEEN CHRONIC LOW BACK PAIN PATIENTS AND CONTROLS
van der Hulst M, Vollenbroek-Hutten MMR, Kupers L, Hermens HJ

EXTRACTION OF DISTINCTIVE COMPONENTS OF MOTOR CONTROL FROM SURFACE EMG IN HEALTHY AND SPINAL CORD-INJURED PATIENTS
Lee DC, McKay WB, Stokic DS, Lee JE, Lim HK, Sherwood AM

MUSCLE ACTIVATION PATTERNS DURING INDEPENDENT AND GRAVITY-COMPENSATED REACH AND RETRIEVAL MOVEMENTS IN ELDERLY PERSONS
Prange GB, Jannink MJA, Kallenberg LAC, IJzerman MJ, Hermens HJ

Sala Londra **Motor Control (*Chairs: Lowery M, Farina D*)**

THE INFLUENCE OF THE FLEXOR DIGITORUM BREVIS MUSCLE ON POSTURAL STABILITY
Okai LA, Kohn AF

A MODEL OF THE NEUROMUSCULOSKELETAL SYSTEM FOR USE IN PRE-CLINICAL TESTING OF JOINT REPLACEMENTS
Doheny E, FitzPatrick D, O'Malley M, Lowery M

EFFECT OF UNILATERAL ELECTRO-ACUPUNCTURE ON FUNCTION OF IPSILATERAL AND CONTRALATERAL TIBIALIS ANTERIOR MUSCLE
Huang L, Zhou S, Lu Z, Brooks L, Tian Q, Li X, Cao L, Yu J, Wang H

THE EFFECT OF MUSCLE FATIGUE ON MOTOR CONTROL IN THE KNEE JOINT
Kasovic M, Medved V, Cifrek M, Matkovic B, Jankovic S, Jukic I

BILATERAL INCREASE IN CORTICOMOTOR EXCITABILITY FOLLOWING INTERVENTIONAL TRANSCRANIAL MAGNETIC STIMULATION (iTMS)
Millar LC, Edwards DJ, Mastaglia FL, Thickbroom GW

WAVELET SMOOTHING AND SELF-ORGANIZED MAPS IN THE ANALYSIS OF POSTURAL RESPONSES
LK Hughey, DH Burns, J Fung

Sala Madrid **Sensor and wearable/ambulatory technology and applications (*Chairs: De Rossi D, Bonato P*)**

MONITORING MOBILITY ASSISTIVE DEVICE USE IN PATIENTS AFTER STROKE
Boissy P, Hester T, Sherrill DM, Corriveau H, Bonato P

WEARABLE FUNCTIONAL STATUS MONITOR FOR PATIENTS WITH STROKE
Roy SH, Cheng S, De Luca CJ, Nawab H, Chang S

A NOVEL INTEGRATED SYSTEM FOR PATIENT HOME MONITORING
Caselli P, Bibbo D, Schmid M, D'Alessio T

INTRODUCTION OF LOCATION FREE MOTION ANALYSIS TOOLS FOR PATIENT TRAINING
Baten C, Smeding JH, Wassink R, Haarmeier C, Luinge H, Gorter M, Geerdink F

WIRELESS BIO-FEEDBACK SYSTEM FOR BALANCE CONTROL
Rocchi L, Farella E, Dozza M, Brunelli D, Benini L, Chiari L

UPPER TRAPEZIUS EMG ACTIVITY DURING SEATED COMPUTER WORK AND IN UPRIGHT POSTURES
Mork PJ, Westgaard RH

h 10.45-11.45 COFFE BREAK and **POSTER SESSIONS: Incontinence and pelvic floor EMG (T03), Gait and movement analysis (T04), Movement disorders (T05), Posture (T13), Sports, elderly and space medicine and human performance (T17), Applications in ergonomics (T20).**

Incontinence and pelvic floor EMG (T03)

T03.P01. NON-INVASIVE ASSESSMENT OF THE GRACILIS MUSCLE BY MEANS OF SURFACE EMG ELECTRODE ARRAYS
Cescon C, Bottin A, Nowakowski M, Herman RM

T03.P02. APPLICATION OF THE ELECTROMYOGRAPHIC BIOFEEDBACK IN THE INCONTINENCE ANAL AND PELVIC FLOOR
Amorim CF, Amorim LJ, Veronesi JJ Ronaldo, Macau HN, Oliveira LVF, Pacheco MTT, Zângaro RA

T03.P03. INTRAOPERATIVE CONFIRMATION OF SURFACE EMG NERVE BUNDLE ENTRY POINT LOCALIZATION OF GRACILIS MUSCLE IN HUMANS
Nowakowski M, Herman R, Salowka, Walega PJ

Gait and movement analysis (T04)

T04.P01. ANALYSIS OF THE MODEL HEMIPARETIC MOVEMENT IN SIT-TO-STANDS IN HEALTHY PERSONS IN PARALLEL BARS
Takagi A, Ishiguro K, Kataoka O, Kurokawa Y

T04.P02. PERTURBATION INCREASES RATE OF MEDIOLATERAL STANCE WIDTH VARIABILITY DURING STEADY STATE GAIT INVESTIBULOPATHIC INDIVIDUALS
Oddsson LIE, Sienko K, Wall III C

T04.P03. LOCATION FREE MOTION ANALYSIS
Baten C

T04.P04. GROUND REACTION FORCES IN THE GAIT IN CONDITIONS OF PATELLOFEMORAL INSTABILITY
Corrêa FI, Corrêa JCF, Gondo RM, Andrade DV, Bérzin F

T04.P05. SOFT TISSUE ARTEFACTS AND MARKERS MISPLACEMENT COMPENSATION BY MEANS OF DOUBLE STEP GLOBAL OPTIMISATION PROCEDURE
D'Amico M, Roncoletta P

T04.P06. COMPARISON OF TECHNIQUES FOR UPPER TRUNK MOTION IN GAIT ANALYSIS
Leardini A, Ferrari A, Berti L, Nativo R, Benedetti MG

T04.P07. A QUANTIFIED ANALYSIS OF ELECTRICAL ACTIVITY IN THE LEGS DURING WALKING AND JOGGING
Gavilanes B, de Gandarias JJG, Bilbao J, De la Cruz J

T04.P08. A COMPARISON OF KINETIC GAIT PARAMETERS FOR 3-13 YEAR OLDS
Chester V, Tingley M, Biden E

T04.P09. MARKERLESS EVALUATION OF SIT-TO-STAND STRATEGY IN GAUSS-LAGUERRE DOMAIN
Goffredo M, Conforto S, Schmid M, Neri A, D'Alessio T

T04.P10. ROLLOVER SHAPE OBSERVATIONS FROM FOUR ANKLE-FOOT PROSTHESES
Mitchell M, Bush G, Kyberd P, Biden E

T04.P11. PRINCIPAL COMPONENT ANALYSIS OF DISTAL RADIAL FRACTURE KINEMATICS DURING CYCLIC ACTIVITIES OF DAILY LIVING
Murgia A, Kyberd PJ, Barnhill T

T04.P12. ESTIMATION OF KNEE CRUCIATE LOADS DURING LIVING ACTIVITIES: STEP UP/DOWN AND CHAIR RISING/ SITTING MOTOR TASKS
Bertozzi L, Stagni R, Fantozzi S, Cappello A

T04.P13. COMPARATIVE ELECTROMYOGRAPHY ANALYSIS OF THE EXTENSION OF LEG DURING GAIT IN A CARRIER OF LEGG - CALVÉ - PERTHES (DLCP) INSIDE AND IS OF THE WATER
Cyrillo FN, Brandão A, Leung A, Ribeiro C, Bernardes C, Abrahão M, Aparecida M, Torriani C

T04.P14. MRI ANALYSIS OF FLEXION MOVEMENT OF THE SHOULDER JOINT
Takei H, Ikeda Y, Furukawa Y, Nitta O, Yanagisawa K, Goto Y, Watanabe S

T04.P15. STUDY OF THE MOTOR BEHAVIOR OF HEALTHFUL VOLUNTEERS AND AFTER STOKE DURING THE GAIT
Corrêa FI, Corrêa JFC, Filoni E, Araújo MA, Bérzin F

Movement disorders (T05)

T05.P01. CORTICOMOTOR FACILITATION ASSOCIATED WITH IMPLICIT AND EXPLICIT MOTOR IMAGERY IN PATIENTS WITH PARKINSON'S DISEASE
Léonard G, Tremblay F, Tremblay L

T05.P02. ELECTROMYOGRAPHIC ANALYSIS OF MOUTH'S ORBICULAR MUSCLE IN INDIVIDUALS CLASS II
Amorim CF, Amorim LJ, Veronesi Junior J Ronaldo, Macau HN, Oliveira LVF, Pacheco MTT, Zângaro RA

T05.P03. EFFECTS OF MYORELAXING SPLINTS ON THE MASTICATORY MUSCLES OF INDIVIDUALS WITH TEMPOROMANDIBULAR DYSFUNCTIONS
Silva MAMR, Vitti M, Vieira e Silva CA, Vasconcelos PB, Souza LG, Hallak JEC, Regalo SCH, Rodrigues da Silva AMB

T05.P04. EFFECT OF PARKINSON'S DISEASE ON ELETCROMYOGRAM AND MECHANOMYOGRAM DURING SUBMAXIMAL AND MAXIMAL ISOMETRIC CONTRACTION
Marusiak J, Kisiel-Sajewicz K, Najwer W, Jaskolska A, Jaskolski A

T05.P05. EFFECTS OF TEMPOROMANDIBULAR DYSFUNCTION ON THE STOMATOGNATHIC SYSTEM - AN ELECTROMYOGRAPHIC ANALYSIS
Rodrigues da Silva AMB, Vitti M, Vieira e Silva CA, Vasconcelos PB, Souza LG, Hallak JEC, Regalo SCH, Silva MAMR

Posture (T13)

T13.P01. COMPARATIVE STUDY OF POSTURE AND ELECTROMYOGRAPHIC ACTIVITY BETWEEN TEMPOROMANDIBULAR DYSFUNCTION AND HEALTHY SUBJECTS
Barbosa CMR, Duarte CL, Bérzin F

T13.P02. ANALYSIS OF THE POSTURAL AND CRANIO-CERVICAL DYSFUNCTION PROFILE IN DYSPHONIC WOMEN
Rodrigues D, Distefano G, dos Santos Berni K, Lopes dos Santos F, Forti F, Guirro R, Silvério K

T13.P03. THE INFLUENCE OF HIGH HEEL SHOES ON LUMBAR LORDOSIS ASSOCIATED TO THE LUMBAR MUSCLES AND GASTROCNEMIUS
Casarin CAS, Caria PHF, Berzin F, Ambrosano GMB

T13.P04. EFFECTS OF WHIPLASH-ASSOCIATED DISORDERS ON POSTURAL CONTROL DURING SITTING
St-Onge N, Côté JN, Patenaude I, Fung J

T13.P05. PRELIMINARY STUDY OF CENTER OF PRESSURE-FEEDBACK CONTROL FUNCTIONAL ELECTRICAL STIMULATION BALANCE TRAINING SYSTEM IN STROKE
Chen S-C, Chen Y-L, Yang T-F, Kan J-H, Tseng S-H, Handa Y, Seki K

T13.P06. POSTURE AND SPINE MODIFICATIONS AFTER TOTAL HIP JOINT REPLACEMENT: EFFECTS OF LEG LENGTH DISCREPANCY CORRECTION
D'Amico M, Ciarrocca F, Liscio G, Serafini P, Tommasini M, Vallasciani M

T13.P07. EFFECTS OF DENTAL OCCLUSION ON DYNAMIC BALANCE
Hosoda M, Takayanagi K, Isozaki K, Ito T, Nakamata O, Furukawa Y, Kubota A, Inoue K, Matsuda T, Morita S

T13.P08. DYNAMIC BALANCE CONTROL IN TRANSFEMORAL AMPUTEES; INDIVIDUAL CONTRIBUTION OF THE PROSTHESIS SIDE
Nederhand MJ, van Asseldonck EHF, van der Kooij H

T13.P09. AGING EFFECT ON POSTURAL MODULATION IN THE TIBIALIS ANTERIOR STRETCH REFLEX
Obata H, Abe M, Nakazawa K, Ohtsuki T, Akai M

T13.P10. AGING EFFECT ON COHERENT ACTIVITIES OF BILATERAL SOLEUS MUSCLES DURING QUIET STANDING
Abe MO, Nakazawa K, Masani K, Akai M

T13.P11. MOTOR CONTROL STRATEGIES TO MAINTAIN BALANCE IN ELDERLY SUBJECTS EVALUATED USING WAVELET TRANSFORM
Araneda Yanez A, Silvestre Aguirre R

T13.P12. DIFFERENT BALANCE STRATEGIES OF ELDERLY AND YOUNG PERSONS SHOWN BY NONLINEAR ANALYSIS
Makabe H, Miwa M, Kaneko K, Mito K, Sakamoto K

Sports, elderly and space medicine and human performance (T17)

T17.P01. THE INFLUENCE OF BODY POSITION ON MUSCLE RECRUITMENT DURING CYCLING IN NOVICE AND ELITE CYCLISTS
Chapman AR, Vicenzino B, Blanch P, Hodges PW

T17.P02. THE INFLUENCE OF CYCLING CADENCE ON LEG MUSCLE RECRUITMENT IN NOVICE AND HIGHLY TRAINED CYCLISTS
Chapman AR, Vicenzino GT, Blanch P, Hodges PW

T17.P03. A WIRELESS INSTRUMENTED PEDAL TO MEASURE FORCE DURING CYCLING
Bibbo D, Schmid M, Conforto S

T17.P04. RELIABILITY OF ELECTROMYOGRAPHY IN COUNTER-MOVEMENT JUMPING
Carvalho A, Mourão P, Ângelo R, Fraga M, Carvalho C

T17.P05. ELECTROMYOGRAPHIC ANALYSIS OF COUNTER-MOVEMENT JUMPING - A COMPARATIVE STUDY BETWEEN DIFFERENT TARGET JUMPING HEIGHTS
Carvalho A, Mourão P, Ângelo R, Fraga M, Carvalho C

T17.P06. RELATIONSHIP BETWEEN EMG AND MUSCLE OXYGENATION IN SYNERGYSTIC MUSCLES DURING DYNAMIC MUSCLE ACTION
Muraoka Y, Kagaya A

T17.P07. TIMING OF ELECTROMYOGRAPHIC ACTIVITY OF ANKLE MUSCLES IN VOLLEYBALL PLAYERS WITH FUNCTIONAL ANKLE INSTABILITY
Suda EY, Cantuária AL, Sacco ICN

T17.P08. ELECTROMYOGRAPHIC ACTIVITY OF ANKLE MUSCULATURE IN VOLLEYBALL PLAYERS WITH FUNCTIONAL INSTABILITY DURING LANDING AFTER BLOCKING
Suda EY, Cantuária AL, Sacco ICN

T17.P09. IN FIELD ACQUISITION OF SLALOM BINDING LOADS IN SNOWBOARDING
Petrone N

T17.P10. WILL THE OVERGROUND CONDITION AFFECT THE IMPACT SHOCK AND LOWER EXTREMITY MUSCLE ACTIVITY?
Kurumadani H, Murakami T, Sasaki H, Miyake K, Yamato K

T17.P11. EFFECT OF ALTERNATING CURRENT FREQUENCY ON ELECTRICALLY-STIMULATED QUADRICEPS FEMORIS KNEE EXTENSION TORQUE AND CURRENT AMPLITUDE
Selkowitz DM, Rossman E, Fitzpatrick S

T17.P12. MICROGRAVITY INDUCED CHANGES TO THE SEMG/FORCE RELATIONSHIP
Roy SH, De Luca CJ, Gilmore LD, Adam A

Applications in ergonomics (T20)

T20.P01. AN INFLUENCE OF GLENOID GEOMETRY ON ISOMETRIC SHOULDER STRENGTH DURING ONE-HANDED ABDUCTION
Gielo-Perczak K, Matz S, An KN

T20.P02. ASSESSMENT OF ERGONOMIC RISK IN LUMBER GRADERS, A REPETITIVE MONO-TASK SAWMILL POSITION
Jones TK, Kumar S

T20.P03. EFFECTS OF OCCUPATIONAL EXPOSURE TO ELECTROMAGNETIC FIELDS ON MENTAL HEALTH
Yousefi HA

T20.P04. LOCALIZATION OF INNERVATION ZONES IN FOREARM EXTENSOR MUSCLES. A METHODOLOGICAL STUDY
Signorino M, Mandrile F, Rainoldi A

T20.P05. SEMG RECORDINGS FROM THE FOREARM MUSCLES DURING ISOMETRIC CONTRACTIONS AT DIFFERENT EFFORT LEVELS
Signorino M, Mandrile F, Rainoldi A

T20.P06. TRUNK MUSCLE RECRUITMENT WHILE LIFTING IN A MOVING ENVIRONMENT
Matthews JD, Albert WJ, Mackinnon SN, Holmes M

T20.P07. COMPUTER RELATED UPPER LIMB MOTOR PATTERNS BY USING DIFFERENT POINTING DEVICES
Padua L, Aprile I, Frasca G, Granata G, D'Agrosa L, Caliandro P, Tonali PA

T20.P08. EVALUATION OF ELECTRODE POSITION EFFECT ON CV ESTIMATION ON UPPER TRAPEZIUS MUSCLE
Cescon C, Rebecchi P, Merletti R

h 11.45-12.45 ORAL PRESENTATIONS

Sala 500 **Physical Medicine and Rehabilitation (*Chairs: Hodges P, Ebenbichler G*)**

TRUNK MUSCLE RECRUITMENT IN LOW-BACK PAIN PATIENTS, DIFFERENT ADAPTATIONS TO THE SAME PROBLEM
van Dieën JH, Cholewicki J

LUMBOSACRAL ORTHOSES REDUCE TRUNK MUSCLE ACTIVITY IN A POSTURAL CONTROL TASK
Cholewicki J, Reeves NP, Everding V, Morrisette DC

RELIABILITY OF POSTURAL STABILITY MEASURES IN PATIENTS WITH CHRONIC IDIOPATHIC LOW BACK PAIN
Leitner C, Maier P, Paul B, Wick F, Ebenbichler G

TRUNK MUSCLE ACTIVITY IS INCREASED DURING EXPERIMENTAL BACK PAIN, BUT THE PATTERN VARIES BETWEEN INDIVIDUALS
Hodges PW, Cholewicki J, Coppieters MW, MacDonald D

Sala Londra **Application in ergonomics (*Chairs: Hermens H, McLean L*)**

A BIOFEEDBACK SYSTEM FOR PHYSICAL REEDUCATION TO AVOID MOVEMENTS CAUSING LOW BACK PAIN.
Thorsen R, Schopman N, Pigini L, Ferrarin M

EFFECTS AND MECHANISMS OF MYOFEEDBACK TRAINING IN FEMALES WITH WORK-RELATED NECK-SHOULDER COMPLAINTS
Voerman GE, Sandsjö L, Vollenbroek-Hutten MMR, Larsman P, Kadefors R, Hermens HJ

EFFECTS OF TASK STRESS ON KEYING FORCE, MUSCLE ACTIVATION AND PERFORMANCE IN COMPUTER WORK
Visser B, Verdonk A, van der Dussen R, van Dieën JH

FATIGUE DURING TEST CONTRACTIONS AMONG WORKERS WITH AND WITHOUT TRAPEZIUS MYALGIA BEFORE AND AFTER WORK
Sjøgaard G, Blangsted AK, Nielsen PK, Olsen HB, Rosendal L, Hansen L, Søgaard K

Sala Madrid **Sensor and wearable/ambulatory technology and applications (*Chairs: Baten C, Sandsjö L*)**

A SMART TEXTILE T-SHIRT FOR LONG TERM MONITORING OF ECG AND EMG SIGNALS
Sandsjö L, Berglin L, Wiklund U, Karlsson M, Östlund N, Bäcklund T, Lindecrantz K, Karlsson S

CONDUCTIVE ELASTOMER SENSORS IN NEUROLOGICAL REHABILITATION
Giorgino T, Quaglini S

SENSORIZED FABRICS FOR HAND POSTURE AND GESTURE DETECTION
Tognetti A, Lorussi F, Derossi D, Zupone P, Acosta S, Mussa-Ivaldi F

EXPERIMENTS IN THE DETECTION OF UPPER LIMB POSTURE THROUGH KINESTETIC STRAIN SENSORS
Giorgino T, Quaglini S, Lorussi F, Tognetti A, De Rossi D

h 12.45-14.00 LUNCH and DELIVERY OF AWARDS

h 14.00-15.00

Sala 500 KEYNOTE LECTURE 5: Francesco Felici
Neuromuscular responses to exercise investigated through EMG

h 15.15-16.15 ORAL PRESENTATIONS

Sala 500 **Sports, elderly and space medicine (*Chairs: Felici F, De Vito G*)**

RELIABILITY OF ELECTROMYOGRAPHY IN SQUAT JUMPING
Carvalho A, Mourão P, Ângelo R, Fraga M, Carvalho C

CORRELATIONS BETWEEN FLIGHT TIME AND SURFACE EMG RESPONSES TO CONTINUOUS JUMPING TEST
Rainoldi A, Gazzoni M, Gollin M, Kratter G, Minetto MA

EMG-ANGLE RELATIONSHIPS OF THE KNEE EXTENSORS IN FEMALE ADOLESCENT ATHLETES
Rousanoglou EN, Boudolos KD

ACQUISITION AND ANALYSIS OF OLYMPIC KAYAK INDOOR PADDLING
Petrone N, Isotti A, Guerrini G

Sala Londra **Motor Units (*Chairs: Adam A, Erim Z*)**

EMGLAB: AN OPEN-SOURCE EMG DECOMPOSITION PROGRAM
McGill KC, Lateva ZC, Marateb HR

COHERENCE BETWEEN MOTOR UNIT DISCHARGE IN RESPONSE TO SHARED NEURAL INPUTS
Lowery MM, Myers LJ, Erim Z

MULTI-CHANNEL MOTOR UNIT NUMBER ESTIMATION: A NOVEL APPROACH
van Dijk JP, van Schaik IN, Bour LJ, Zwarts MJ, Stegeman DF

COHERENCE BETWEEN EEG AND MOTOR UNIT DISCHARGES
Erim Z, Valsan G, Worrajiran P, Conway BA

Sala Madrid **Movement disorders (*Chairs: Disselhorst-Klug C, Merletti R*)**

EFFECTS OF SCALING FROM NARROW TO WIDE STANCE ON VOLUNTARY STEP INITIATION IN PARKINSON'S DISEASE
Mancini M, Rocchi L, Chiari L, Horak FB

CORTICOMOTOR FACILITATION IN THE QUADRICEPS: A COMPARATIVE STUDY IN YOUNG, OLD AND PARKINSON'S DISEASE (PD) SUBJECTS
Tremblay F, Tremblay LE

QUANTITATIVE EVALUATION OF LOCOMOTOR FUNCTIONS IN PATIENTS IN THE EARLY STAGES OF PARKINSON S DISEASE
Carpinella I, Rabuffetti M, Calabrese E, Mazzoleni P, Nemni R, Ferrarin M

DIAGNOSING PATIENTS WITH ANTERIOR KNEE PAIN
Merkado E, Plotkin D, Benjuya N

h 16.15-16.45 COFFE BREAK and POSTER REMOVAL

h 16.45-18.00 ORAL PRESENTATIONS

Sala 500 **Sports, elderly and space medicine (*Chairs: Orizio C, Minetto M*)**

MICROGRAVITY INDUCED CHANGES IN THE CONTROL OF MOTOR UNITS
De Luca CJ, Adam A, Hayes G, Roy SH, Gilmore LD

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Sala Londra **SEMG Signal Processing (*Chairs: McGill K, Holobar A*)**

QUANTIFYING BURST AND TONIC ELECTROMYOGRAPHIC MOTOR-CONTROL CHARACTERISTICS: SIMULATION, FREQUENCY DOMAIN FILTERING AND TIME SERIES ANALYSIS
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SPASTICITY ASSESSMENT: THE NEED FOR STANDARDIZATION
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A COMBINED METHOD FOR THE CLINICAL ASSESSMENT OF SPASTICITY
Voerman GE, Burridge JH, Hitchcock RA, Hermens HJ

PATHOLOGICAL CLONUS: A CENTRAL OR A PERIPHERAL DISORDER ?
de Vlugt E, Meskers CGM, Abbink DA, De Groot JH, Arendzen H(JH), van der Helm FCT

MOTOR UNIT DECOMPOSITION OF LAYRNGEAL MUSCLES IN SPASTIC DYSPHONIA
Roark RM, Pitman MJ

h 18.00-18.30 CLOSING CEREMONY (Sala 500)

EMG Modeling

SIMULATION OF MOTOR UNIT ACTION POTENTIALS THROUGH A POINT DISTRIBUTION MODEL

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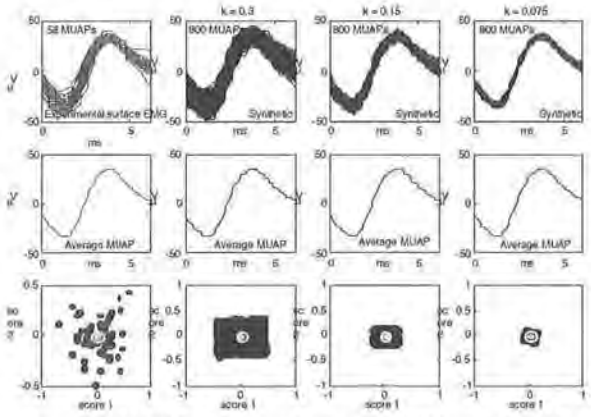
1) Reading University, UK
2) University of New Brunswick, Canada

AIMS: An important stage in the simulation of electromyographic signals is the generation of artificial motor unit action potentials (MUAPs). Synthetic MUAPs may be positioned at their occurrence time yielding a motor unit action potential train (MUAPT). An artificial EMG signal is obtained by linearly combining a set of MUAPTs plus noise. This structural model is often employed for testing the performance of tools, known as EMG decomposition tools, which aim to extract MUAPs from EMG signals. This work focuses on the simulation of MUAPs based on experimental data. For this a Point Distribution Model (PDM), which is a statistical model, is used. We show that some parameters of this model allow for a simple way of controling the shape of MUAPs, which could represent shape changes of MUAPs belonging to the same motor unit over time. We also illustrate that the PDM model gurantees that MUAPs originated from the same source or motor unit (MU) share common imformation.
METHODS: The PDM of a random vector $\mathbf{X}$ is given by $x_c = x_m + \mathbf{Pb}$, where x_c is a new instance of $\mathbf{X}$, x_m is the expectation of $\mathbf{X}$, $\mathbf{P}$ is an array of eigenvectors obtained from the autocorrelation matrix of $\mathbf{X}$ and $\mathbf{b}$ is a random vector that indicates how much variation is exhibited with respect to each of the eigenvectors. A typical interval for generation of $\mathbf{b}$ is $[-k\lambda^{1/2}, k\lambda^{1/2}]$, where k is an user-defined constant and λ are eigenvalues of $\mathbf{P}$. The eigenvectors with larger eigenvalues correspond to the directions of larger variation in the underlying data. Therefore a PDM can be seen as a statistical model of the global shape variation of the training set $\mathbf{X}$, which can be in practice a set of experimental MUAPs. Note that new instances of $\mathbf{X}$, x_c, share a common information x_m, and they are unique because of the random nature of $\mathbf{b}$. In order to illustrate the use of a PDM for generation of artificial MUAPs a MUAP library containing more than 900 MUAP samples, extracted from surface experimental EMG signals obtained from 10 distinct subjects, was built. Signals were detected from the First Dorsal Interosseous of subjects executing isometric contraction during abduction of the index finger. A single pair of Ag/AgCl surface electrodes (diameter = 1 mm, inter-electrode distance = 1.5 mm) was employed. Signals were digitized and amplified via a commercial system (Bagnoli 2 Delsys amplifier).
RESULTS: Figure shows a typical example of application of a PDM for simulation of MUAPs. First an experimental MUAP data set (1st column) is modelled and then synthetic signals are generated from this model (columns 2 to 4). Simulations with different values of k are included. The effect of this parameter is better exemplified at the third row of the figure. MUAPs were projected onto a 2-dimensional space by means of principal component analysis (PCA). Smaller values of k yields patterns closer to average patterns (2nd row). Note also that the PDM model gurantees a constant MUAP template independent of the value of k.
CONCLUSIONS: This work introduces the use of a PDM for simulation of MUAPs based on experimental data. As this is a statistical model it takes into account the variablity of the modelled data set through eigenvector and eigenvalues estimated from the data. This model can be used as a basic unit of a tool for simulation of electromyographic signals.



Example of MUAP simulation. (First row) MUAP waveforms. The first column is a set of experimental MUAPs whereas the others are synthetic MUAPs obtained from a PDM with k = 0.3, k = 0.15 and k = 0.075. (Second row) MUAP template or average. (Third row) Scatter plot of first and second scores obtained from the principal components of MUAPs. The data centre is highlighted with a circle

A MODEL OF ELECTRICAL STIMULATION

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AIMS: To develop a mathematical model and analytical solution for a problem of muscle electrical stimulation inducing muscle contraction. Two models of the volume conductor have been considered. 1) A planar, two tissue, grounded model, constituted by fat and muscle tissues, with a fat layer placed both over the muscle and below; the stimulation current is delivered over the first fat surface, the second fat surface is grounded. 2) A planar, three layer model, with skin, fat and muscle tissues, with stimulation current delivered over the skin surface and no grounded surface (it is only assumed that the potential vanishes at infinity).
METHODS: Two planar, multi-layer (skin, fat, muscle), an-isotropic models of a physiological tissue (referred to as volume conductor) are studied. Both conductivity and permittivity of the volume conductor are considered, dispersion is neglected. The analytical solution is obtained in the two dimensional Fourier transform domain, transforming in the planes parallel to the volume conductor surface. The model is efficient in terms of computational cost as the solution is analytical (only numerical Fourier inversion is needed). It can provide the current distribution in layers below the skin when an electrical current is delivered at the skin surface.
RESULTS: The two models of volume conductor have been compared. Small differences in the current path within the muscle can be observed only close to the grounded fat layer. Thus only the three layer model was further studied. Two representative examples of application of the model have been considered. 1) Simulation of stimulation artifact during transcutaneous electrical stimulation. Only the effect of tissue permittivity is considered, neglecting the other sources of artifact (as the capacitive coupling between the stimulating and recording electrodes). The exponential tail (for a single channel) and the decay of the stimulation artifact (between channels along the muscle fibres) for increasing distance from the stimulation site can be simulated. The effect of different simulated anatomies can be studied (i.e., for different conductivities, permittivities, tissue thickness). Furthermore, the effect of different stimulation waveforms can be simulated. 2) Simulation of interferential therapy. The amplitude modulated current distribution within the muscle was simulated. The model can provide useful indications for the design of optimal stimulation paradigms in interferential therapy.
CONCLUSIONS: A mathematical model for the simulation of electrical stimulation inducing muscle contraction is developed. Simulation of stimulation artifact and of interferential therapy are suggested as possible applications. The same solution method could be applied in other fields in which the estimation of the electrical current distribution in a medium induced by the injection of a current from the boundary of the medium is of interest.

ESTIMATING THE ACCURACY OF EMG DECOMPOSITION RESULTS

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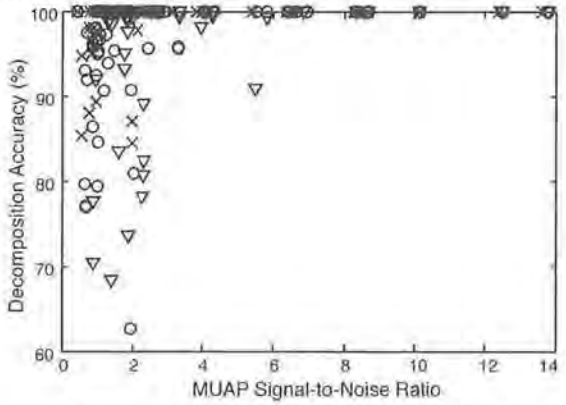
2) Isfahan University, Isfahan, Iran

AIMS: Proper interpretation of scientific results obtained using EMG decomposition requires an objective assessment of their accuracy. Decomposition accuracy can be checked directly by cross-checking results obtained from multiple electrodes, but this is not always practical. Another approach is to estimate accuracy based on signal characteristics. This requires a validation study using cross-checkable real signals or synthetic signals to establish the accuracy that can be achieved for signals of different complexities.
METHODS: We synthesized EMG signals of different complexities from a database of real motor unit action potential (MUAP) waveforms from monopolar needle and fine-wire recordings. The signals were decomposed independently by three different operators using EMGLAB, an interactive EMG decomposition program. The results were compared with the known signal parameters. The accuracy of each MUAP trains was computed as $(N_C/N_T)(1-N_E/N_T)$, where N_C is the number of correct identifications (within 0.5 ms), N_E is the number of false positives (incorrect by more than 5 ms), and N_T is the total number of discharges. The accuracy was plotted against the signal-to-noise ratio (SNR) of the MUAP, defined as the Euclidean distance between the MUAP and the next most similar MUAP, divided by the RMS signal amplitude.



Decomposition accuracy achieved by three operators

RESULTS: The results are shown in Figure. For large MUAPs (SNR > 2), the three operators achieved accuracies of 96%, 82%, and 100% at least 90% of the time. These results not only show that high decomposition accuracy can be achieved, but they also show that different accuracy can be expected from different operators.
CONCLUSIONS: This study reveals several important points: 1. The accuracy with which a MUAP train can be decomposed depends on the MUAP itself and on the signal in which it occurs. The same degree of accuracy cannot necessarily be expected for different MUAPs in the same contraction or for the same MUAP in different contractions. Therefore accuracy must be assessed individually for each MUAP in each signal. 2. The precision with which a MUAP's time of occurrence can be identified is limited by physiological uncertainty related to conduction-velocity variability and by measurement error due to noise and waveform variability. 3. From a practical point of view, accuracy should be reported by a single index with a simple intuitive meaning. This index should take into account missed identifications, time-of-occurrence errors, and false positives, but not true negatives (which over-inflate accuracy). 4. Estimation of decomposition accuracy must take into account a MUAP's signal-to-noise ratio (with the noise consisting of both background noise and interference) and its similarity or dissimilarity to other MUAPs. We believe that more widespread reporting of the accuracy of decomposition results will help both investigators and the scientific community to more reliably interpret the validity of those results.

SIMULATIONS OF SURFACE ELECTROMYOGRAFIC SIGNALS IN A DISTRIBUTED ENVIRONMENT (GRID)

Gazzoni M, Lo Conte L, Merletti R
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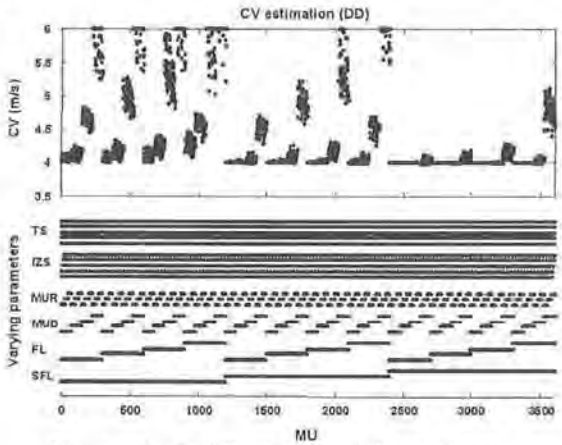
AIMS: Several simulation studies exist in literature in order to clarify the effect of anatomical factors on surface electromyographic signal (SEMG) parameters. Usually, these studies are focused on a limited number of parameters because of the heavy computational load of these simulations. To overcome these limitations we implemented a distributed environment (GRID) for SEMG simulation.
METHOD: To setup the GRID, we adopted the Berkeley Open Infrastructure for Network Computing (BOINC) middleware, which is based on the concept of "volunteer computing". We adapted the SEMG model proposed by Farina et al. [1] to run in this distributed environment and used the model to investigate the effect of multiple anatomical factors on motor unit (MU) conduction velocity (CV) estimation. CV is an important physiological parameter for muscle characterization. However, its estimation is affected by the anatomical characteristics of the subject. In this study, we considered several parameters expected to influence CV estimation: MU radius, MU depth, fat layer thickness, fiber length, and MU innervation and tendon zone spread. The actual CV was set to 4 m/s and parameters varied within a physiologically plausible range. All together, we simulated 3600 MUs of a 100 fibers each. CV was estimated from the simulated double differential signals with "virtual" electrodes placed between the innervation zone and the tendon.
RESULTS: The time needed to complete a simulation scales linearly with the number of computers available in the GRID. Figure 1 shows CV estimation as a function of all parameters. The observed overestimation of the CV is mainly due to the combined effect of the MU depth and fat layer thickness, and is particularly evident for shorter fibers.
CONCLUSIONS: A GRID environment allows to reduce linearly with the number of available computers the time needed for SEMG simulation, therefore making possible to conduct complex simulations with a high number of varying parameters. This study highlights once more how critical CV estimation is.

[1] Farina D, Mesin L, Martina S, Merletti R, A surface EMG generation model with multilayer cylindrical description of the volume conductor. IEEE Trans Biomed Eng. 2004 Mar;51(3):415-26.



CV estimation for different anatomical characteristics. Fixed model parameters: limb radius: 50 mm, bone radius: 20 mm, skin thickness: 1 mm, skin conductivity: 0.5 S/m, fat conductivity: 0.05 S/m, muscle conductivity: 0.1 S/m (transversal), 0.5 S/m (longitudinal), interelectrode distance: 10 mm, conduction velocity: 4 m/s. Varying parameters: semi-fiber length (SL: 50, 70, 90 mm), fat layer thickness (FL: 1, 3, 5, 10 mm), MU depth (MUD: 3, 5, 10, 15 mm), MU radius (MUR: 0.5, 1, 3 mm), IZ spread (IZS: 0, 5, 10, 15, 20 mm), tendon spread (TS: 0, 5, 10, 15, 20 mm).

T01.P01
SIMULATION OF SURFACE EMG SIGNALS FOR A MULTI-LAYER VOLUME CONDUCTOR WITH TRIANGULAR MODEL OF THE MUSCLE TISSUE

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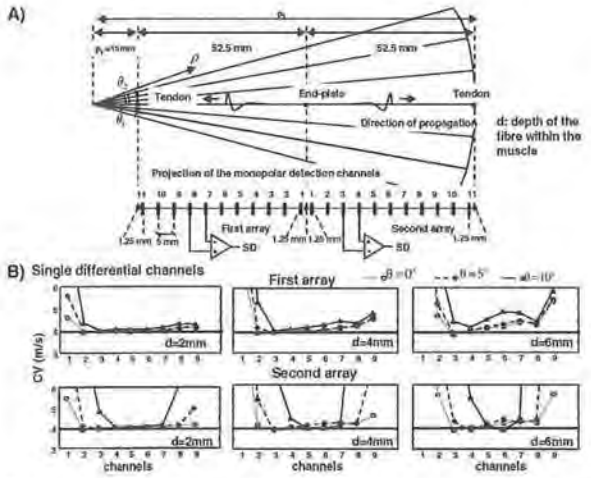
AIMS: Surface EMG signal simulation has important applications in testing algorithms for parameter estimations and in interpreting experimental EMG data. This study analytically describes surface EMG signals generated by a model of a triangular muscle, i.e., a muscle with fibres arranged in a fan shape. Examples of triangular muscles in the human body are the deltoid, the pectoralis major, the trapezius.
METHODS: A model of triangular muscle is proposed. It is a sector of a cylindrical volume conductor (with the fibres directed along the radial coordinate). The muscle conductivity tensor reflects the fan an-isotropy. Edge effects have been neglected. A solution of the non-space invariant problem for a triangular muscle is provided in the Fourier domain. An approximate analytical solution for a two plane layer volume conductor model is obtained by introducing a homogeneous layer (modelling the fat) over the triangular muscle. The results are implemented in a complete surface EMG generation model (including the finite length of the fibres), simulating single fibre action potentials.
RESULTS: The model is not space invariant due to the changes of the volume conductor along the propagation of the action potentials. Thus the detected potentials at the skin surface change shape as they propagate. This determines problems in the extraction and interpretation of parameters. The influence of the in-homogeneity of the volume conductor in CV estimation is addressed. Different fibre depths, electrode placements and small misalignments of the detection system with respect to the fibre have been simulated. The CV estimate is largely biased when the depth of the fibre increases, when the detection system is not aligned with the fibre and close to the innervation point and to the tendons. CV estimates with bias less than 10% were obtained only in the case of superficial fibres (less than 4 mm depth within the muscle), aligned with the detection system (less than 5° misalignment), far from the end-plate and tendons. Values with more than 50% bias were obtained in the worst simulated conditions (channels close to the innervation region or tendons, misalignment 10°, 6 mm depth of the fibre within the muscle).
CONCLUSIONS: In a triangular muscle surface EMG signal variables are largely affected by the volume conductor and by the fibre arrangement.

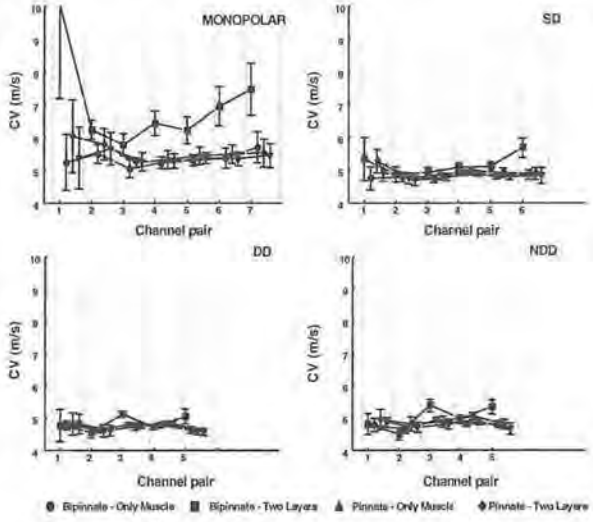


A) model of triangular muscle. Two electrode arrays are simulated.
B) estimated CV as a function of the detection array and position of the muscle fibre.

T01.P02
ESTIMATION OF MUSCLE FIBER CONDUCTION VELOCITY IN PINNATE MUSCLES: A SIMULATION STUDY

Mesin L[1], Farina D[2]
1) LISiN, Dept. of Electronics, Politecnico di Torino, Torino, Italy
2) Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

AIMS: The aim of this simulation study was to assess the feasibility of estimating muscle fibre conduction velocity (CV) from surface electromyographic (EMG) signals in muscles with one and two pinnation angles.
METHODS: The volume conductor consisted of a layered medium simulating anisotropic muscle tissue and isotropic homogeneous subcutaneous tissue. The muscle tissue was homogeneous in case of one pinnation angle and inhomogeneous for bipinnate muscles (two fibre directions). Interference EMG signals were obtained by simulating recruitment thresholds and discharge patters of a set of 100 or 200 motor units for the pinnate and bipinnate muscle, respectively. CV was estimated from two surface EMG channels in case of monopolar, single differential, double differential, and Laplacian recordings. The simulated CV value was 4 m/s.
RESULTS: Estimates of CV from the pinnate and bipinnate muscle are shown in the Figure. The bias in CV was on average larger than 0.8 m/s in all cases.
CONCLUSIONS: The main factors affecting CV estimates were the end-plate and end-of-fibre components due to the scatter of the projection of end-plate and tendon locations along the fibre direction, as a consequence of pinnation. The same problem arises for muscles with the line of innervation zone locations not perpendicular to fibre direction. These results provide an interpretation of the positive bias in CV estimates from surface EMG signals, usually observed in experimental conditions.



Estimated CV for the four models considered (pinnate and bipinnate, with and without subcutaneous layer) for monopolar (A), single differential (B), double differential (C), and Laplacian (D) recordings.

Grants: The Danish Technical Research Council (project "Centre for Neuroengineering (CEN)", contract n° 26-04-0100) and the European Community (project "Cybernetic Manufacturing Systems (CyberManS)").

T01.P03
A FINITE ELEMENT MODEL FOR DESCRIBING THE EFFECT OF MUSCLE SHORTENING ON SURFACE EMG

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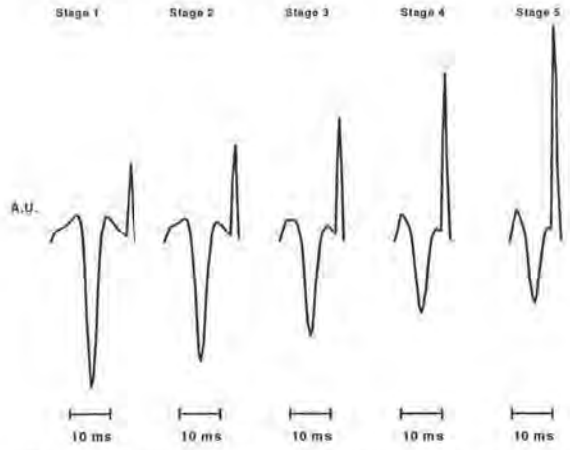
3) Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

AIMS: A finite element model for the generation of single fibre action potentials in a muscle undergoing various degrees of fibre shortening is developed. The effect of the volume conductor shortening on surface EMG parameter is assessed.
METHODS: The muscle is assumed fusiform with muscle fibres following a curvilinear path described by a Gaussian function. Different degrees of fibre shortening are simulated by changing the parameters of the fibre path and maintaining the volume of the muscle constant. The conductivity tensor is adapted to the muscle fibre orientation. In each point of the volume conductor, the conductivity of the muscle tissue in the direction of the fibre is larger than that in the transversal direction. Thus, the conductivity tensor changes point-by-point with fibre shortening, adapting to the fibre paths. An analytical derivation of the conductivity tensor can be obtained. The volume conductor is then studied with a finite element approach using the analytically derived conductivity tensor.
RESULTS: Five contraction levels were simulated. The geometrical changes in the muscle, which imply changes in the conductivity tensor, determined important variations in action potential shape, thus affecting its amplitude and frequency content (Figure). The relative weights of the travelling components and of the end-of-fibre component changed with shortening (Figure). Average rectified value (ARV) and mean power spectral frequency (MNF) estimated from the simulated single fibre surface potentials were influenced by muscle shortening, mainly due to the change in the distance between sources and detection electrodes with shortening. For example, for a channel placed between the innervation zone and tendon and fibre under the detection point and 6.25 mm deep, ARV and MNF were -27% and 87% (monopolar detection), and -48% and -7% (single differential) with respect to the values with the muscle 46.6% shortened. The variations of ARV and MNF strongly depended on the position of the fibre within the muscle.
CONCLUSIONS: The model provides a new tool for interpreting surface EMG signal features with changes in muscle geometry, as it happens during dynamic contractions.



Example of monopolar potentials for different shortening levels (relaxed, 13.3%, 26.7%, 40%, 46.6%), for a fibre under the detection electrode (placed between the innervation zone and the tendon), 6.25 mm deep into the muscle

T01.P04
AN ANALYTICAL MODEL FOR SURFACE EMG GENERATION IN VOLUME CONDUCTORS WITH SMOOTH VARIATION IN CONDUCTIVITY

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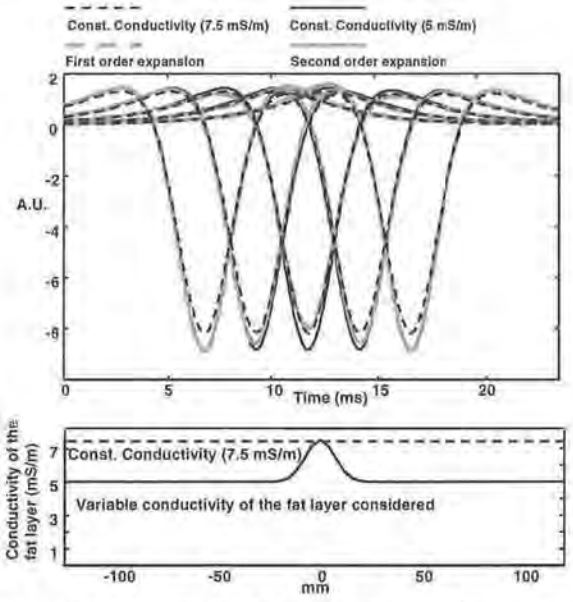
2) Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

AIMS: In this study we provide an analytical description of a non-space invariant volume conductor for surface EMG signal generation. The volume conductor presents a variation in conductivity along the direction of the muscle fibres. This may reflect the practical situation of tissues with different conductivity properties in different locations or of transitions between tissues with different properties.
METHODS: The volume conductor comprises planar layers representing the muscle and subcutaneous tissues. The muscle tissue is homogeneous and anisotropic while the subcutaneous layer is inhomogeneous and isotropic. The inhomogeneity in the subcutaneous layer is modelled as a smooth variation in conductivity along the muscle fibre direction. The problem is studied in the two-dimensional Fourier domain with spatial angular frequencies corresponding to the longitudinal and perpendicular direction with respect to the muscle fibres, in planes parallel to the detection surface. Regular perturbation theory was applied, representing the solution as a series expansion. This leads to a set of Poisson's problems, for which the source term in an equation and the boundary conditions are determined by the solution of the previous equations. This set of problems is solved iteratively, obtaining approximations of higher order at each step. The series expansion is truncated for the practical implementation, leading to an approximate solution.
RESULTS: The model was implemented in Matlab and showed high convergence rate. A second order expansion indeed provided an approximation with negligible error with respect to higher orders (Figure). A smooth change in the simulated conductivity of the subcutaneous layer determined a perturbation in the shape of the surface potential in the direction of source propagation (Figure). The perturbation depended on the position of the source, thus the model is not space invariant.



Representative simulation of single fiber action potentials generated by the proposed model in case of homogeneous volume conductor and in case of Gaussian variation of conductivity of the subcutaneous layer, with zero order, first order, and second order expansions.

CONCLUSIONS: The proposed model constitutes a new approach for surface EMG signal simulation with applications related to the validation of methods for information extraction from EMG signals.

T01.P05
ESTIMATION OF NERVE FIBER CONDUCTION VELOCITY DISTRIBUTIONS WITH INGRAM'S COLLISION TECHNIQUE: RESULTS OF A COMBINED NERVE-MUSCLE MODEL

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AIMS: Collision techniques are a potentially powerful tool in clinical neurophysiology, as they provide information on the nerve fiber conduction velocity distribution (CVD). The aim of the study was to evaluate the accuracy of Ingram's collision technique [1] with a new model which describes stimulation of the nerve fibers and generation of motor unit action potentials.
METHODS: The model consisted of a nerve model of two-point stimulation and of a muscle model that simulated the generation of surface EMG. The input to the nerve model was the pattern of stimuli (Ingram's collision technique: a proximal stimulus followed by simultaneous distal and proximal stimuli [1]). The nerve fibers were assigned a rheobase based on linear cable models in an infinite homogeneous medium. Lapique's space-clamped model was used for the activation process. All nerve fibers had the same recovery cycles. The muscle model generated motor unit action potentials from a layered planar volume conductor [2]. The motor unit action potentials were delayed according to the nerve model output and summated to produce the electrically evoked responses (Figure). Ingram's technique was simulated for five conditions: muscle fiber CVD with mean 4 m/s and standard deviation 0.3m/s (control condition), and mean and standard deviation of muscle fiber CVD changed by ±25% with respect to the control condition. In each condition, 19 simulations were performed with random location of the motor units within the muscle to simulate different anatomies. In all simulations, nerve fiber CVD had 5%, 50%, and 95% percentiles of 48.3m/s, 60.2m/s, and 70.6m/s, respectively. The estimated CVD from the simulated signals was compared with the simulated CVD to assess the relative estimation error.
RESULTS: The estimated nerve fiber CVDs had 5%, 50%, 95% percentiles of 50.0±1.52m/s, 63.9±1.10m/s, and 78.0±1.07m/s, respectively (control condition). When the mean value of muscle fiber CVD was increased by 25% the estimated nerve fiber CVDs had percentiles 50.1±1.23m/s (5%), 64.1±0.92m/s (50%), and 78.4±1.88m/s (95%). The relative error in percentile estimation did not depend on the mean and standard deviation of muscle fiber CVD. The error increased from 5% (3.53±3.16%) to 50% (6.17±1.82%) and 95% (10.36±1.51%) percentile ($P << 0.0001$).

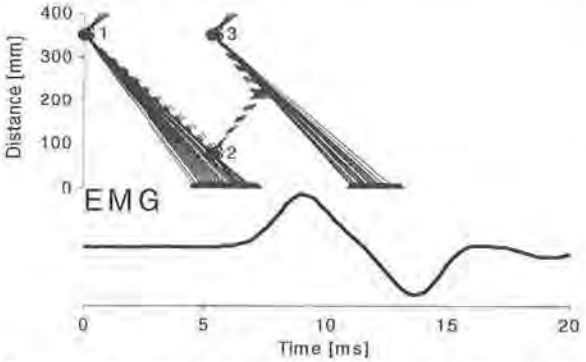

Figure: An illustration of the simulated response to Ingram's collision technique. Blocked action potentials are drawn with dotted lines. The origin of the y-axis correspond to the position of the muscle.

CONCLUSION: The accuracy of the estimated nerve fiber CVD with Ingram's collision technique increases with decreasing nerve fiber conduction velocity. Furthermore, changes in the distribution of muscle fiber CVD do not influence the accuracy of the technique.

[1] Ingram DA, Davis GR, Swash M. "The double collision technique: a new method for measurement of the motor nerve refractory period distribution in man." Electroencephalogr Clin Neurophysiol. 1987 Mar;66(3):225-34.
[2] Farina D, Merletti R. "A novel approach for precise simulation of the EMG signal detected by surface electrodes." IEEE Trans Biomed Eng. 2001;48(6):637-46.

T01.P06
A SIMULATION STUDY FOR A SURFACE EMG SENSOR THAT DETECTS DISTINGUISHABLE MOTOR UNIT ACTION POTENTIALS

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AIMS: The purpose of this study was to design a surface EMG sensor that could be used with our Precision Decomposition technique, which extracts motor unit firing patterns from multichannel EMG signals.
METHODS: An advanced volume conductor model [J.H. Blok D.F. Stegeman, H.J. Blok, A.V. Oosterom, Ann. Biomed. Eng., 30: 313-326, 2002] was used to simulate the surface detected motor unit action potential (MUAP) due to motor units located at different depths within the muscle tissue. Seven types of electrode configurations were investigated by summing the monopolarly detected surface MUAPs on a square grid of 9 point electrodes according to the spatial filter characteristic of each configuration. The following spatial filters were investigated: longitudinal single differential (LSD), transversal single differential (TSD), longitudinal double differential (LDD), transversal double differential (TDD), normal double differential (NDD), bi-transversal double differential (BiTDD), and inverse binomial of order two (IB2). Because of the symmetry of the simulation setup around the center row of the electrode array, which was aligned with the muscle fiber axes in a fixed position between innervation zone and tendon, we investigated 16 different configurations. The criterion of the energy of the difference (EOD) between the MUAP shapes was used to rank electrode configurations with respect to their ability to distinguish two motor units located at different depths. Using the same criterion we then ranked pair wise combinations of electrode configurations by their ability to generate different MUAP shape representations of the same motor unit.
RESULTS: For all motor unit depth difference investigated, the EOD values for the two possible BiTDD configurations, each using 6 electrodes, were always at least 10% greater than those of the other configurations. Based on this criterion, the BiTDD configurations were the best for maximizing the shape difference between two MUAPs. The next best configurations were a particular TSD and TDD configuration, each using 2 or 3, respectively, electrodes of the array. The influence of interelectrode distance on EOD values between the MUAPs of two motor units was investigated for three spacing values: 1.6 mm, 2.3 mm, and 3.1 mm. The results indicated that the EOD values changed little in the investigated spacing range. Among the 120 pair wise combinations of electrode configurations one pair, comprised of a TSD and a BiTDD configuration, always showed the greatest EOD values for all the depth differences investigated. The pair's average EOD value was 39% higher than the second place, which was shared by two configuration pairs.
CONCLUSIONS: Using the results of the EOD calculations, a 4-channel detection system using all 9 available electrodes is proposed. The implications of using only 6 electrodes, effectively reducing skin contact area in half, are discussed.

This work was supported by the post-doctoral fellowship program

of the Korean Science and Engineering Foundation (KOSEF), a NICHD (NCMRR) grant # R24HD38585, and a NASA grant # 99E192.

T01.P07
RELATIONSHIP BETWEEN RESTRICTION OF CHEWING MOVEMENT FUNCTION AND 8- HYDROXY-2'-DEOXYGUANOSIN

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AIMS: The ingestion, movement, sleep, and excretion, et al are necessary in maintaining the life. However, the report is hardly about relevance of chewing movement function and the oxidation stress. Then, we examined that relationship between the chew movement function control and the oxidation stress.
METHODS: Thus, as for the authors, oxidation stress advocates a hypothesis to be caused by the restriction of chewing movement function. We measured a level of 8- hydroxy-2 '-deoxyguanosine (8-OHdG) of one person which enforced a chin cure correction. The 8-OHdG check is a competitive in vitro enzyme-linked immuno-sorbent assay for quantitative detection of the oxidative DNA adduct 8-OHdG. 8-OHdG could be the index of oxidation stress. A level of 8-OHdG were measured from each urine sample taken on the operation before, the day, four day after, and after 1,4,8,12 weeks. A level of 8-OHdG were detected with average of three detected samples.
RESULTS: The accuracy of the measured 8-OHdG level showed a high value in urine (as 0.96). 8-OHdG level increased after an operation and the restriction of chewing movement function (Figure 1).
CONCLUSIONS: The increasing of oxidation stress not only operation, but also restriction of chewing movement function was suggested.

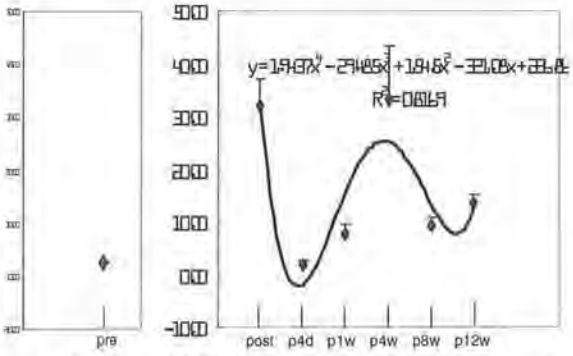

Figure 1 A change of 8-OHdG level in urine by an operation and a food intake limit

T01.P08 EFFECTS OF BONDED RAPID MAXILLARY EXPANSION APPLIANCES ON MASTICATORY MUSCLES PERFORMANCE DURING MASTICATION

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AIMS: The bonded maxillary expansion appliances with full interocclusal acrylic coverage have been reported to have certain advantages over conventional rapid maxillary expansion used by Orthodontics. However, there are no studies reporting the effects of the use of this appliance on masticatory muscles. The aim of the present work was to evaluate, by surface electromyography analysis (EMG), the effects of the used of the bonded maxillary expansion appliance on masticatory muscles performance during mastication.
METHODS: The sample consisted of 28 children, both sexes, between 7 and 10 years old, presenting skeletal posterior cross bite that required treatment with rapid maxillary expansion. The electromyographic activity of right and left masseter muscle (RM and LM) and right and left temporalis muscle (RT and LT) was analyzed before treatment (T1), one week of appliance used (T2), one month of appliance used (T3) and four months of appliance used (T4). EMG activity was evaluated during habitual chewing (10 sec) and during maximal voluntary dental clenching (4 sec). The MyoSystem - Br1 electromyographer was used with differential active electrodes (silver bars 10mm apart, 10mm long, 2mm wide, 20x gain, input impedance 10GΩ and 130dB CMRR). The EMG signal was analogically amplified with gain of 1000x, filtered and sampled by 12 bits A/D convert board with a 2KHz frequency. Electromyographic data of envoltory frequency of habitual chewing were normalized by envoltory frequency of maximum voluntary dental clenching and the data were statically analyzed (SPSS 10.0 software). The mean differences between T1XT2XT3XT4 were evaluated for each muscle using the GLM repeated measures analyses. This study was approved by the Committee of Ethics in research from faculty of Odontology of Ribeirão Preto-USP.
RESULTS: Comparing T1XT2, the EMG activity of MD increased and the EMG activity of ME, TD and TE decreased. However, the difference was statistically significant only to TE ($p<0,05$). Comparing T1XT3, the EMG activity of RM, LM and RT increased and the EMG activity of LT decreased, however no one difference was statistically significant. Comparing T1XT4, the EMG activity of RM, RT and LT increased and the EMG activity of LM decreased, however no one difference was statistically significant.
CONCLUSIONS: Based on these results, it could be concluded that the bonded maxillary expansion appliance did not altered significantly the masticatory muscles performance during mastication.

T01.P09
ESTIMATION OF PARAMETERS IN THE DIMITROV-DIMITROVA SFAP MODEL

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INTRODUCTION: In order to analyze real SFAPs using SFAP models, it is interesting to relate waveform parameters to internal model parameters. In this work we try to estimate two parameters of the Dimitrov-Dimitrova (D-D) SFAP model [1] from two SFAP waveform parameters.
METHODS: In the D-D model, a SFAP is formed as the convolution of an excitation source and an impulse response. The excitation source is modelled by 4 parameters: A_2, A_{2r}, A_3 and T_{spr}. The impulse response is expressed as a function of the axial distance (z_0), the constant of anisotropy (K_{an}), the fibre diameter (d), and the radial distance (r). Calling V_1 and V_2 to the main positive and negative peaks in the SFAP waveform, we define the duration of the first phase (DFP) as the time interval corresponding to the SFAP amplitude increase from $0.1 \cdot V_1$ to V_1; and the rise time (RT), as time interval between peaks V_1 and V_2. We use DFP to estimate the radial distance, and then we use RT to estimate A_2.
RESULTS: In Fig. 1 we show the dependence of parameters DFP (Fig.1a) and RT (Fig.1b) on both the excitation parameters (upper row) and impulse response parameters (bottom row).

We note that only r has a significant influence on DFP. As K_{on} is usually fixed to a constant value, and assuming that the variability among fibre diameters in a muscle is small, we can use parameter DFP to estimate r. On the other hand, we note that only r, A_2 and A_3 have a considerable influence on RT (Fig. 1b). We can neglect the influence of K_{on} and d and use the previous r estimation. As only the A_2/A_3 ratio is important in a SFAP, we can fix the value of A_2, and find a good estimation of A_3 directly from RT.

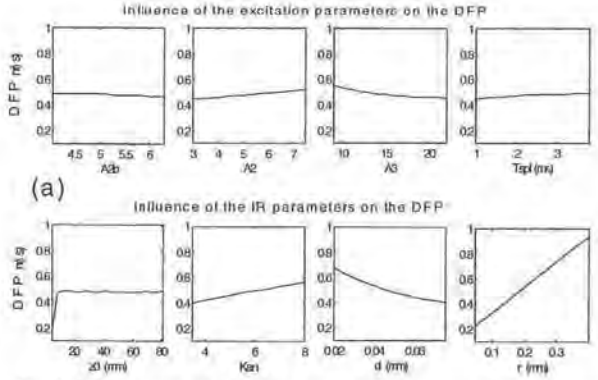
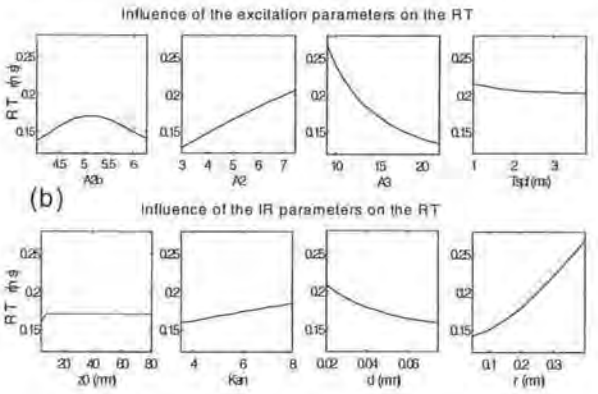


Fig. 1. (a) Influence of excitation and impulse response parameters on DFP and A_3 in the D-D model.



CONCLUSION: By using two waveform parameters (DFP and RT) of a SFAP, we can estimate the values of two parameters of the D-D model, namely the radial distance and A_3. This method is useful in the analysis of real SFAPs and fibrillation potentials.

[1] G. Dimitrov, N. Dimitrova. "Precise and fast calculation of the motor unit potentials detected by a point and rectangular plate electrode", Med Eng Physics, 1998, pp. 374-381.

T01.P10
PROPOSAL FOR ELECTRICAL INSULATION OF THE SIGNAL ACQUISITION MODULE

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AIMS: To analyze the interference in a signal acquisition module (MAS) EMG1000 (Lynx® - 10^9 Ohms, 16 bits and range of ±1V), as well as to develop of proposal for a system that guarantees the quality of signal acquisition.
METHODS: Four (4) experimental procedures were determined: 1) MAS connected in accordance with the manufacturer's recommendations, that is to say, MAS was connected to the electrical network (EN) (AC - 60 Hz) by means of a 12 volt and 1 AMP feed source and it was connected to the desktop by means of an 8-way cable network (CN); 2) the MAS was removed from the EN and fed by a battery with a capacity of 10 AH of 12 volts, and it remained connected to the desktop by CN; 3) the MAS was connected to the EN, but it was connected to the desktop by means of fiber optic (FO); 4) a system of electrical insulation of the equipment was mounted with the MAS connected to a battery and it was connected to the desktop by FO. The experiment was divided into two stages: Initially the noise coming from the collection system was assessed by means of a short-circuit between the active and the reference electrodes. The second stage consisted of collecting the rest electromyographic signal of the right brachial biceps muscle. At the two stages, the signals were collected under the 4 above-mentioned conditions, for 10 seconds and repeated 3 times. Use was made of a bipolar surface electrode (LYNX®) simple differential active (gain 20x, IRMC>100dB), with sampling frequency of 2000 Hz and band-pass filter of 20-1000Hz (*Butterworth*). The reference electrode was placed on the sternal manubrium. RMS and median frequency (MF) were assessed with Matlab® 6.5.1 software.
RESULTS: With regard to the noise generated by the collection system, under condition 1 the RMS was 2.73 μV and MF of 54.69 Hz. Under condition 2 the RMS was 0.58 μV and the MF 410.16 Hz. With procedure 3 the RMS was 1.85 μV and the MF 54,16 Hz. Under condition 4 there was a reduction in interference, the RMS being 0.58 μV and the MF 416,06 Hz. As regards the collection of electrical activity at rest of the brachial biceps muscle, when the acquisition system was connected in accordance with condition 1, the RMS was 5.39 μV and MF of 117.19 Hz. Under condition 2, the RMS was 2.54 μV and the MF 54.69 Hz. Whereas under condition 3, the RMS was 4.16 μV and the MF identical to condition 1. In turn, under condition 4, the RMS was 2.01μV and the MF 7.81 Hz.
CONCLUSIONS: According to the results, the electrical insulation proposed under condition 4 was efficient for eliminating the noise, guaranteeing the quality of the acquired signal.

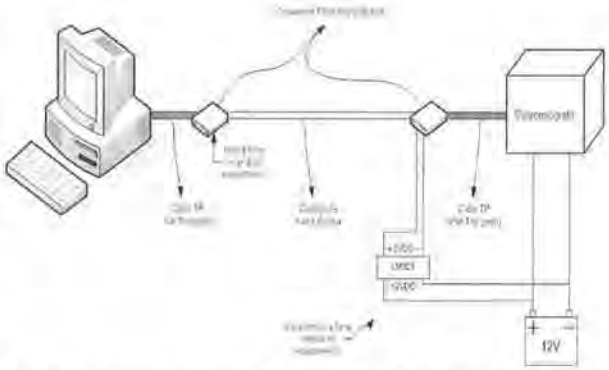

Figure 1 - Assembly Diagram of the electrical insulation in the Lynx® signal acquisition module.

T01.P11
BEHAVIOR OF THE ELECTROYMYOGRAPHIC VARIABLES ALONG THE THICKEST PART OF THE MUSCLE

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AIMS: To assess the electromyographic activity in five electrode positions (P2, P1, M, D1 and D2) on the thickest part of the straight thigh muscle (RC) at 50% of the maximum voluntary isometric contraction (MVIC).
METHODS: An evaluation was made of 33 volunteers (23.29 2.4 years of age) without lower member pathologies. All of them signed a term of free and informed consent and the research was approved by the Institution's Ethical Committee on Research.

Use was made of an EMG1000 (Lynx®, 10^9 Ohms, 16 bits and inlet band of ±5V) signal acquisition system and for capturing the action potentials of the RC muscle, 5 bipolar surface electrodes (LYNX®) simple differential active (gain 20x, IRMC>100dB) were used, with band-pass filter of 20-1000 Hz (*Butterworth*) and sampling frequency of 2000Hz. For electromyographic collection, the volunteers remained seated on a Bonet table, with their trunks fixed, thigh at 90° and leg with 105° flexion. Firstly, the skin was trichotomized and cleaned with 70% alcohol. Next, the location of the motor point of the straight thigh was determined, with the aid of transcutaneous electrical stimulation. The electrodes were positioned, starting with the motor point (M), two being placed in the distal position (D) and two in the proximal position (P) equidistantly. The reference electrode was placed in the anterior tuberosity of the tibia. The force of leg extension was measured by means of a MM-100 (KRATOS®) load cell. The signals were collected simultaneously for 5 seconds, repeated 3 times with 1-minute intervals. RMS and mean frequency (MF) were analyzed with Matlab® 6.5.1. software. Statistical analysis was done with the Wilcoxon test ($p<0.05$).

RESULTS: With regard to RMS (μV), the highest value was obtained with electrode D2 (31.94±10.50) and the lowest with P1 and M (20.06±6.97; 22.07±7.40) when compared with the other positions (P2: 25.20, 10.58 and D1: 25.82±10.34). As regards the median frequency (Hz), this had an inverse behavior being lower in the distal portion (D1: 49.48±5.59; D2: 49.64 ±5.30) and higher on the motor point (M: 50.19±6.01) and proximal portion of the thickest part of the muscle (P1: 52.00 ±8.26; P2: 50.36±7.13).

CONCLUSIONS: It was found that there is variability of the electromyographic signal along the thickest part of the muscle, the amplitude being lower at the motor point and higher at the distal extremity of the muscle and the behavior of the frequency is antagonistic to that of the RMS.

T01.P12
EFFECT OF DEAFNESS ON MASTICATORY CYCLE EFFICIENCY: ELECTROMYOGRAPHIC ANALYSIS

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AIMS: Electromyography has been used to study the performance of the musculature in mastication, swallowing and speech and is an important tool for the analysis of physiopathological changes affecting this musculature. Most deaf individuals present strong dysfunction in facial and masticatory musculature, temporomandibular dysfunctions, bruxism and constant headaches, with no directly relation with deafness. The aim of this study was to analyze electromyographically of right (RM) and left (LM) masseter and right (RT) and left (LT) temporal muscles in deaf individuals comparing them with clinically normal individuals.

METHODS: This was performed in 30 individuals from both genders with mean age of 23.0±5 years, divided into 2 groups of 15 individuals each: 1. deaf individuals; 2. clinically normal individuals (controls), during clinical condition of mastication. A five channels electromyograph MYOSYSTEM - BR1 - DataHomins Tecnologia Ltda was used, with simple differential electrodes. Statistical analysis was performed using the software "Statistical Package for the Social Sciences" SPSS version 10.0 (Chicago, IL) by Student's paired t test.

RESULTS: The normalized eletromyographic means was: Group 1: RM: 0.25±0.11; LM: 0.29±0.17; RT: 0,24±1.15; LT: 0.24±0.13.

Group 2: RM: 0.21±0.09; LM: 0.21±0.11; RT:0,20±0.08; LT: 0.20±0.06. The difference between group 1 and group 2 was not statistically significant.

CONCLUSIONS: It was concluded that deaf individuals do not show impaired performance and efficiency in inferior masticatory cycles compared to health controls.

T01.P13
BEHAVIOR OF THE EMG SIGNAL DURING ISOMETRIC ACTION IN INCREMENTED RESISTED EXERCISE

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AIMS: To verify the behavior of medium frequency (Fmed) and Root Mean Square (RMS) of EMG signal, during isometric actions in incremented resisted exercise of type Leg Press 45°.

METHODS: After the approval by the Committee of Ethics in Research at UNIMEP, protocol 102/2004, twelve healthy men varying 21±1,67 years of age, weight 78,12±13,06 Kg, cutaneous bend of right thigh of 13,00±4,88 mm and percentile of fat per electric impedance of 19,2±5,31% were selected for the study. The volunteers were submitted to tricotomy and asepsis with alcohol 70% in both thighs and 2 electrodes were positioned according to recommendation of SENIAM in the right and left straight femoral muscle (RFD and RFE). After, they were submitted to experimental incremented procedure relating the percentile of 1 maximum repetition (1RM), beginning with 3% of 1RM and increased of 3 in 3% until the load of fatigue installation (CIF). The series were composed by 1 minute of static contraction and 2 minutes of rest between each contraction. The registration EMG of RFD and RFE were accomplished during the static contractions by three serial times of 5 seconds and after CIF in the 3rd, 6th and 9th minutes. The data were normalized by the value of 1RM. An electromiograph of the brand LYNX® was used with sampling frequency of 2KHz and 2 active surface simple differential electrodes. The processing of the signal was accomplished by the software MATLAB 6.5 and the pertinent statistical treatment was accomplished by the software GraphPad Instat 2.01, adopting the index of significance of 5% and interval of trust of 95%.

RESULTS: CIF was of 24,08±1,36%1RM. Anova One-Way test with post hoc of Dunnett did not evidence significant statistical differences among the relative loads to for 1RM as well as for the rest and aftterwards CIF for RFD, even so for RFE significant statistical differences were evidenced ($p<0,05$) up to 24%1RM. Extremely significant difference was verified ($p<0,001$) of rest for the loads of 18, 21 and 24% for RMS when applied test of Friedman followed by the test of Dun to locate the differences found. In Fmed the statistical differences found when Mann-Whitney U test was applied was $p<0,007$ of rest for the loads of 3,6 and 9.

CONCLUSIONS: The data suggest: a) there was different behavior between the values normalized for CIF of the muscle RFD and RFE, b) there was a behavior of stabilization of Fmed up to 24% of 1RM not evidencing a causal relationship between intensity of proposed effort and Fmed, c) there was a growing behavior of RMS up to 24% of 1RM evidencing a causal relationship between intensity of effort and shot of motor units; this also corroborates with the pattern of motor recruitment.

EMG Signal Processing

NONINVASIVE ANALYSIS OF MOTOR UNIT DISCHARGE PATTERNS IN ISOMETRIC FORCE-VARYING CONTRACTIONS

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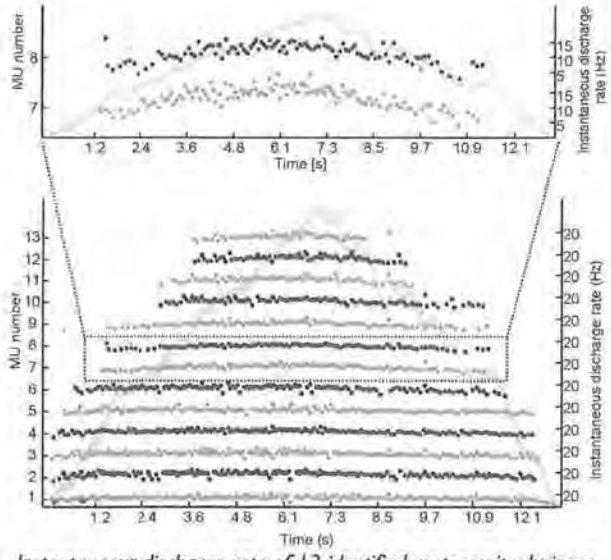
AIMS: The aim of the study was to investigate the feasibility of identification of single motor unit discharge pattern from multi-channel surface EMG in force-varying contractions. For this purpose the Convolution Kernel Compensation (CKC) technique [1] was applied to surface EMG signals recorded during isometric force-varying contractions.

METHOD: Eight healthy male subjects (age, mean ± SD, 27.3±2.2 yr, height, 1.79± 0.07 m, weight 75.2±7.4 kg) participated to the study. Surface EMG signals were acquired by a 5 13 electrode grid (with the four corner electrodes missing; inter-electrode distance 3.5 mm). The signals were recorded in single differential configuration during isometric contractions of the dominant abductor pollicis muscle with force linearly increasing (decreasing) from 0% to 10% (and vice versa) of the maximal voluntary contraction (MVC) force in 12 s. The signals were amplified (LISiN-Ottino Bioelettronica, Rivarolo, Torino, Italy), band-pass filtered (3 dB bandwidth, 10-500 Hz) and sampled at 1650 Hz by a 12 bit A/D converter. The CKC method [1] was applied to the detected surface EMG signals in order to reconstruct motor unit discharge patterns.

RESULTS: On average, the number of detected motor units was 14.1±3.8. Motor units were progressively recruited with increasing force. Newly recruited MUs had initial discharge rate of 8.6±1.4 pulses per second (pps) and gradually increased discharge rate with increasing force (peak discharge rate 14.0±4.3 pps). Average inter-pulse interval (IPI) variability, when divided by the mean IPI, was 13.8±5.3 %. The motor unit discharge rate just before derecruitment was 8.5±1.7 pps. The order of derecruitment was the inverse of the recruitment order (Figure). Motor unit recruitment threshold and peak discharge rate were significantly inversely correlated (R=-0.38, P < 0.001). Finally, motor unit action potentials as detected by the electrodes of the grid were extracted by spike triggered averaging using the identified discharge instants as trigger. All the extracted surface action potentials exhibited stable shape over time revealing location of MU innervation zones, length of the fibers, and propagation in the fiber direction.



Instantaneous discharge rate of 13 identified motor units during a linearly increasing and decreasing ramp force contraction (maximum force: 10% MVC)

CONCLUSIONS: The CKC method can extract motor unit discharge patterns in low-level (0-10% MVC) force-varying isometric conditions. The method is not sensitive to superimpositions of action potentials and detects on average a larger number of motor units that it is usually possible with single-channel intramuscular EMG.

[1] Holobar A., Zazula D.: Correlation-based decomposition of surface EMG signals at low contraction forces, Med. Biol. Eng. Comput., 2004, Vol. 42, No. 4, pp. 487-495.

AN ALGORITHM FOR OPTIMAL DISCHARGE SELECTION FOR MUAP WAVEFORM EXTRACTION

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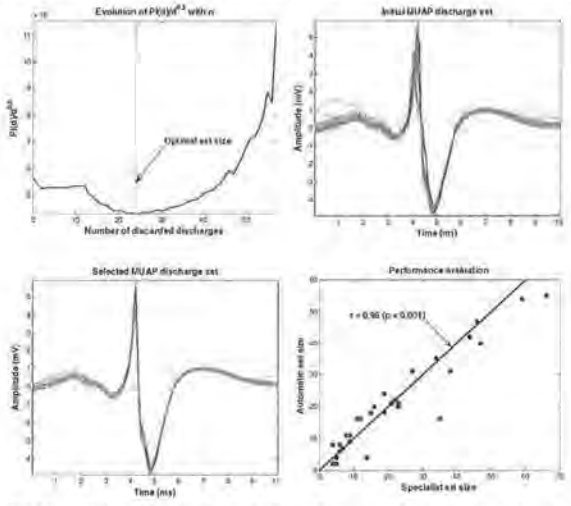
AIMS: We present an algorithm that selects a subset of discharges from a MUAP set extracted by a decomposition algorithm [1]. This procedure is devised as a previous stage to MUAP waveform averaging, trying to avoid the effects of artefacts from other MUAPs, needle movement, equipment noise, etc.

METHODS: 5 s-long continuous EMG signals were recorded from tibialis anterior normal muscles, using concentric needle electrodes during different contraction levels. 32 MUAP trains were obtained from the raw EMG signals using a decomposition algorithm developed at Montreal University [1]. In the method, the waveforms of the isolated discharges of each MUAP are aligned in the time axis by maximum correlation and in the voltage axis by Euclidean distance minimization. The selection algorithm iteratively eliminates the discharge that is the most distant in the Euclidean sense to the average of MUAP discharges, until just two discharges are left. On each iteration, a perturbation index (PI) is calculated by computing the standard deviation (SD) of the discharge amplitudes at every sample time, and then averaging throughout the signal time extent. The final set of selected discharges is obtained minimizing the function PI(d)/sqrt(d) (where d is the number of valid discharges in each iteration) (Figure a).



PI(d)/sqrt(d) (a); MUAP set before (b) and after (c) the selection; evaluation results (d)

RESULTS: In all the analyzed MUAPs along the different range of contraction activity, removal of distorted discharges was satisfactory (Figures b,c). Discharges selection performed by an expert electromyographist yielded a high correlation with automatic results (r=0.95; p<0.01) (Figure d). Taking the expert's

measures as the gold standard, the error of the automatic results was almost unbiased (m=1.17) with moderate SD (s=5.38).
CONCLUSIONS: The presented method is able to obtain automatically a large number of minimally distorted discharges from a MUAP set obtained from EMG decomposition.

[1] Florestal JR, Mathieu PA, Malanda A. "Analysis of intramuscular EMG signals with a decomposition program". XVth Congress of the International Society of Electrophysiology and Kinesiology (ISEK 2004), June, 2004.

BLIND OPTIMIZATION OF WAVELETS FOR SEPARATION OF NON-STATIONARY SURFACE EMG SIGNALS

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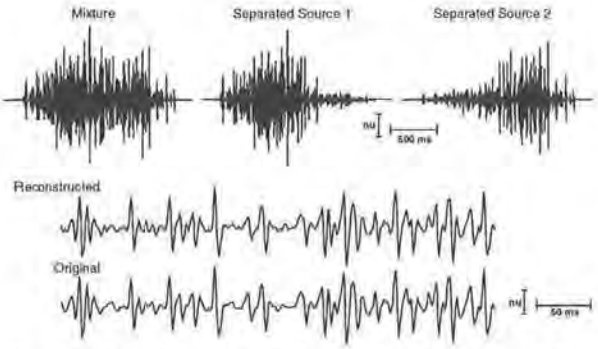
AIMS: Surface EMG signals detected over the skin surface are often mixtures of signals generated by many active muscles, due to crosstalk. To separate signals generated by different muscles, a blind source separation (BSS) approach can be adopted [1]. In this study we propose a novel approach for BSS in which the rotation step is based on spatial wavelet transformation of the whitened observations. We also adopt parametrization of the mother wavelet and propose its optimization.
METHODS: A linear instantaneous signal mixture model is assumed. The method proceeds in two steps: 1) estimation of a "spatial whitening matrix", and 2) estimation of the "missing rotation matrix". The whitening step is performed by estimating the eigenvalues and eigenvectors of the spatial autocorrelation matrix of the observations [1]. For the rotation step, we propose the joint diagonalization of a set of Spatial Wavelet Distributions (SWDs) of the whitened observations. The SWDs depend on the mother wavelet which can be optimized by unconstrained parametrization (filter length L = 4 in this study) via the lattice parameterization [2]. The blind criterion for optimization of the mother wavelet is the minimization of the average of the crosscorrelation function between the reconstructed sources at time lags close to the zero lag (from 0 to 4 in the results reported here). The method has been tested on simulated and experimental surface EMG signals. Three mixtures of simulated signals with 10dB signal-to-noise ratio were generated by a multi-layered cylindrical volume conductor model. The sources were two muscles with elliptical shape (semi-axes 3.5 mm and 10 mm) at a distance of 9.8 mm. The two muscles were activated by a Gaussian excitation level profile (maximum excitation level 80% and 40%, peak level at 0.7 s and 1.3 s, respectively). Experimental signals were detected from the flexor carpi radialis and pronator teres during flexion/extension contractions [1]. The results were compared with those obtained with the use of Wigner-Ville and Choi-Williams time-frequency distributions.



Example of simulated signals before (top row, Mixture) and after (top row, Separated Source 1 and 2) separation by BSS with optimized wavelet. Detail of a smaller signal portion to show the similarity between original and reconstructed source after BSS (bottom row).

RESULTS: The Figure shows an example of source separation of simulated signals. On simulated signals, the average (±SD, over 25 simulations) crosscorrelation between the original and separated sources after BSS (index of performance) was 0.90±0.04 (optimized wavelet), 0.83±0.06 (worst wavelet), 0.83±0.08 (Wigner-Ville), and 0.87±0.07 (Choi-Williams). On experimental signals (4 subjects), the index of performance was 0.78±0.10 (optimized wavelet), 0.56±0.15 (worst wavelet), 0.64±0.13 (Wigner-Ville), and 0.73±0.12 (Choi-Williams).
CONCLUSIONS: The new BSS approach proved to be superior to previously proposed time-frequency-based BSS methods in both simulated and experimental EMG signals.

[1] Farina D, Fevotte C, Doncarli C, Merletti R. Blind separation of linear instantaneous mixtures of nonstationary surface myoelectric signals. IEEE Trans Biomed Eng. 2004;51:1555-67.
[2] Maitrot A, Lucas MF, Doncarli C, Farina D. Signal-dependent wavelets for electromyogram classification. Med Biol Eng Comput. 2005;43:487-92.

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INDEPENDENT COMPONENT ANALYSIS AND HIGH-DENSITY EMG GRID IN MUSCLE FORCE ESTIMATION

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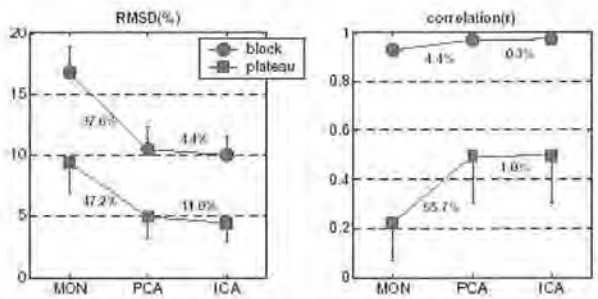
AIMS: The use of high-density EMG grids can yield substantial improvements in muscle force estimation. For the subsequent analysis it is crucial how to reduce the large number of EMG signals to a single force signal. A statistical method to reduce redundancy in high-density EMG is principal component analysis (PCA) [1]. The aim of the present study is to investigate whether independent component analysis (ICA) results in further improvements regarding muscle force estimation.
METHODS: Eleven healthy subjects performed isometric block-shaped arm extensions at three levels of maximum voluntary contraction (20, 50, 80%MVC). Surface EMG of the triceps brachii and force output were measured simultaneously. The EMG consisted of an active monopolar (MON) electrode grid (13×10 electrodes). After high-pass filtering the EMG at 10 Hz, three analysis methods (i.e. MON, PCA, ICA) were applied. Then, signals were rectified, summed, compensated for electromechanical delay, and low-pass filtered (10 Hz). To qualify force estimation the root mean squared difference (RMSD) and the correlation between force and processed EMG signals were computed, both over the entire time series (block) and over a region of constant force (plateau).
RESULTS: A repeated measures one-way ANOVA showed a significant effect ($p<0.01$) of analysis method on muscle force estimation (Figure). Compared to MON, PCA improved force estimation by 42.4±6.8% and 30.0±36.3% for RMSD and



Quality of muscle force estimation (RMSD/corr) for three different analyses: MON, PCA, and ICA. Markers indicate mean and error bars the SD over the entire block and over the plateau region

correlation, respectively. ICA showed a further improvement of 7.8±4.7% and 0.6±0.5%.
CONCLUSIONS: Supporting an earlier study [1], the comparison with a monopolar montage (Figure) revealed that PCA of a grid of EMG signals improved muscle force estimation by far. The present results clearly showed that force estimation was improved not only over the entire block pattern but also within the fine-tuning fluctuations between force and EMG during the plateau region. In general, PCA ranks signals by means of their covariance structures and is, thus, unbiased regarding underlying sources (or muscle fiber direction). ICA additionally exploits the correlation structure of the signal, i.e. it extracts independency. Here, we found that EMG-based force estimates using ICA can be even better than the ones built on PCA. Both improvements, PCA and ICA, might be explained by a (spatial) summation of signals that lack random, destructive superimposition caused by, e.g., variable firing rates. Unbiased methods like PCA or ICA that address covariance and correlation appear rather useful for (pre-)processing multivariate EMGsignals in order to estimate the resulting forces.

[1] Staudenmann et al, IEEE TBME, in press, 2006

ENTROPY-BASED OPTIMIZATION OF SPATIAL SELECTIVITY IN SURFACE EMG DETECTION WITH WAVELET SPATIAL FILTERS

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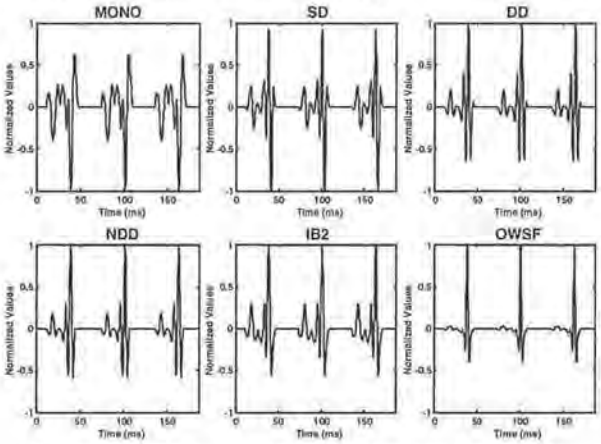
AIMS: Classic surface EMG recordings have poor spatial selectivity due to the low-pass filtering effect of the volume conductor. This makes it difficult to distinguish the contribution of single motor units from the interference signal. The aim of the study was to improve selectivity in multi-channel surface EMG detection with a new class of spatial filters, optimized on a signal-by-signal basis.
METHODS: Two-dimensional surface EMG signals were decomposed with a spatial dyadic wavelet transformation on 4 sub-bands. The low-pass band coefficients were zeroed and the signal reconstructed. This was equivalent to apply a high-pass spatial filter. The mother wavelet for the decomposition was parameterized as described in [1], and optimized on a signal-by-signal basis. The optimization criterion was the minimization of the temporal entropy of the output signal. A lower number of action potentials indeed decreases entropy, which is maximum when all signal samples are equal. The method was tested on simulated and experimental surface EMG signals. Simulated signals [2] were generated as detected by a 3 3 grid of electrodes with 5.0 mm interelectrode distance, in case of 1, 2 and 3 active motor units. Experimental signals were acquired with a 3 3 electrode grid from 8 healthy male subjects (age, mean ± SD, 25.3 ± 1.8 yr) from the biceps brachii muscle during contractions against gravity with elbow 10 degrees flexed. The duration of the simulated motor unit action potentials and the ratio between the main motor unit action potential amplitude and the amplitude of the action potential of more distant motor units were used to compare the proposed signal-based spatial filter (OWSF) with monopolar (MONO), bipolar (SD), double differential (DD), normal double differential (NDD), and inverse binomial of second order (IB2) recordings [3]. In experimental recordings the ratio between average rectified value and peak-to-peak amplitude of isolated action potentials was used as performance index.
RESULTS: The Figure shows the application of the proposed spatial filter to simulated signals as compared with classic spatial filters. The optimal filter based on wavelets allows the extraction of a single source with almost complete suppression of the contributions from the other two sources. In simulated signals, the duration of the action potential (simulations with one motor unit) was 17.8 ± 0.3 ms (N = 10; MONO), 14.5 ± 1.2 ms (SD), 15.4 ± 1.2 ms (DD), 14.2 ± 0.7 ms (NDD), 16.9 ± 0.7 ms (IB2), and 10.8 ± 2.7 ms (OWSF). The ratio between the amplitude of the action potential from a distant and close motor unit (8 mm distant) was 33.7% (MONO), 22.2% (SD), 18.3% (DD), 16.1% (NDD), 24.2% (IB2), and 3.0% (OWSF). In experimental signals, the ratio between average rectified value and peak-to-peak amplitude of isolated action potentials was 27.9±5.9 ms (MONO), 16.6±6.8 ms (SD), 17.2±7.5 ms (DD), 15.8±5.1 ms (NDD), 23.4±6.4 ms (IB2), and 11.2±2.1 ms (OWSF; significantly smaller than all others, $P < 0.05$).
CONCLUSIONS: The entropy-based wavelet spatial filter significantly improved spatial selectivity of the EMG recordings with respect to previously proposed filters. The method can be extended to the need to extract specific sources (e.g., close vs far sources) in surface EMG recordings.



Simulated monopolar (MONO), single differential (SD), double differential (DD), normal double differential (NDD), inverse binomial (IB2) recordings compared with the application of the signal-based spatial filter proposed in this study (OWSF)

[1] Maitrot et al. Med Biol Eng Comput. 2005;43:487-92.
[2] Farina et al. IEEE Trans Biomed Eng. 2004 Mar;51(3):415-26.
[3] C. Disselhorst-Klug et al. IEEE Trans Biomed Eng. 1997 44(7):567-74.

This work was supported by the Danish Technical Research Council (project "Centre for Neuroengineering (CEN)", contract n° 26-04-0100).

AN EXPERT SYSTEM TO SUPPORT THE INTERPRETATION OF SURFACE EMG IN GAIT ANALYSIS

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AIMS: Next to kinematics and kinetics, surface EMG is an essential part of gait analysis, providing the physician with objective information about the individual muscular coordination pattern during movement. As the information is based on the activation pattern of different muscles, several EMG signals have to be recorded simultaneously. Consequently, the process of signal interpretation is fairly complex and depends essentially on the expertise of the clinician. To date, it is mostly performed visually and qualitatively. Artificial Intelligence supporting the interpretation of surface EMG signals and the resulting muscular co-ordination patterns could overcome these limitations. Such a system based on the fuzzy-inference-method has been successfully introduced by Disselhorst-Klug et.al. supporting the interpretation of the muscular coordination pattern of ankle joint movement during gait. However, due to the limitation of ankle joint the previous approach has been extended to the entire lower extremity chain.
METHODS: An expert-system consists of a knowledge-base, which contains the human expertise, and an inference engine, which processes the input variables based on the knowledge base and merges them to meaningful output variables. However,

the surface-EMG signals themselves, as well as the way to interpret them, contain some degree of uncertainty that makes the definition of precise rules for decision making impossible. The fuzzy logic or fuzzy sets theory is tolerant of imprecise data and, therefore, well suited to build an expert system to support the interpretation of the muscular coordination. The use of linguistic variables facilitates the acquisition of knowledge, especially from non-technical experts, and the integration of different types of knowledge from various experts. In standard clinical gait analysis Surface-EMG signals are recorded from eight muscles in order to assess the muscular co-ordination patterns of the joint movements during gait. The commonly observed muscles are tibialis anterior, soleus, gastrocnemius, rectus femoris, vastus lateralis, biceps femoris, adductor longus and gluteus medius. Simultaneously, the gait cycle of each patient is determined using foot switches and videotapes. The knowledge-base of the expert system contains rules for the hip, the knee and the ankle joint relating to the eight muscles. The rules are in linguistic terms, e.g. for the muscular coordination: "*If TibAnt is active and Soleus is active, then Effectiveness of dorsiflexion low*" or for the mechanics of the limb chain: "*If ankle joint in extension, knee joint in extension and hip in extension during monopedal stand, the Effectiveness is high*" The fuzzy inference methodology performs a prediction of the effectiveness of the muscular coordination of the three joint movements during gait based on these rules.

RESULTS: In a first attempt the feasibility and correctness of the expert system was verified by example measurements of healthy subjects and patients with spasticity. The results are promising, but further studies are required to assess the correlation with the kinematical data.

CONCLUSIONS: The expert-system predicts the effectiveness of all lower limb joint movements in gait reliable. It supports the interpretation of the muscular co-ordination pattern detected by surface-EMG and thus makes this information accessible for clinical routine.

QUANTIFYING BURST AND TONIC ELECTROMYOGRAPHIC MOTOR-CONTROL CHARACTERISTICS: SIMULATION, FREQUENCY DOMAIN FILTERING AND TIME SERIES ANALYSIS.

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AIMS: The electromyographic signal of muscle activity during continuous, repetitive movement contains more information than just amount of activity. The pattern or "shape" of muscle activity, be it continuous-tonic or modulated and burst-like in fashion, gives an indication of the functional role of musculature in the movement task. These characteristics are thought to change in motor control dysfunction (such as low back pain), but are inherently difficult to quantify. This paper presents the development of a method used to quantify these electromyographic (EMG) characteristics.

METHODS: An EMG simulation platform was developed using tonic EMG signals collected from subjects during an isometric biceps brachii task. Phasic EMG signals were generated by superimposing a half-wave rectified sine-wave at repeated points. The height (input phasic-tonic ratio [input PTR]) and width of the sine-wave could be modulated to represent different EMG characteristis. The simulation platform was validated against a subset of data from the lumbo-pelvic muscles during a rapid-repetitive lower-limb movement task. The frequency domain filtering generated a "linear envelope" of EMG from the simulated data, with different filter frequencies tested. Subsequent time-series analysis involved maxima and minima detection and consequent calculation of a ratio of the two (output PTR). Time-series peak detection required the optimisation of the width Ω (as proportion of movement cycle) and threshold Ψ (as the value at the {total number of data points$*\Psi^{th}$} data point) values for peak detection. Filtering and analysis parameter performance were defined according to average mean-squared-error between input and output PTR over increasing burst height and also across burst width.

RESULTS: Depending on the muscle modelled, the simulation platform matched between 78.3±0.6% to 83.8±0.5% of the muscle's linear-envelope. In instances of purely tonic (continuous) EMG, this value was 82.1±0.5%. Based upon the optimisation performance assessment calculations, the ideal filtering and analysis method involved a 10Hz low pass Bessel filter, with threshold (Ψ) and width (Ω) settings of 0.35 and 0.5 respectively. Generally, the low pass filter settings of 5 and 10 Hz performed the best along with threshold (Ψ) settings between 0.35-0.5 and width (Ω) settings between 0.25-0.5.

CONCLUSIONS: We present a novel frequency-domain and time-series analysis method to quantify EMG characteristics for motor control analysis. We consider the simulation model fit to real EMG data to be adequate given the ranges of goodness of fit as compared to the goodness of fit measure for pure tonic (continuous) activity. No "gold-standard" for such goodness of fit exists, however. The 10Hz low-pass filter smooths the EMG data allowing more accurate time-series measurements. To our knowledge no other method to date permits the measurement of such "shape" characteristics in motor control and this method may be used in future motor control studies.

EVALUATION OF NONLINEAR PREDICTION METHODS IN DEMODULATED EMG SIGNALS FROM RESPIRATORY MUSCLES

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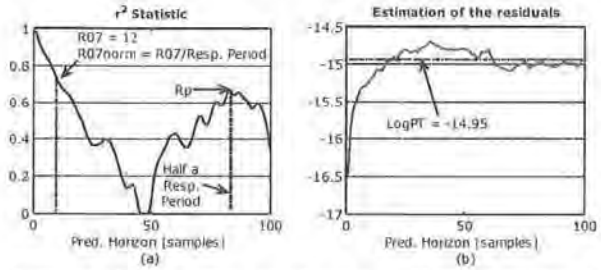
AIMS: Analysis of respiratory muscles activity is an interesting tool for the evaluation of pulmonary diseases. EMG signal has already been analyzed by means of many linear techniques. On the other hand, other methods have been recently applied in order to evaluate nonlinear dynamics of EMG signal. It is already known that respiratory rhythm generation/pattern formation occurs via a nonlinear oscillator. Thus, the activation of the different respiratory muscles can be produced by nonlinear mechanisms, as well. The aims of this work are two: 1) to evaluate nonlinear models fitting and prediction in demodulated EMG signals from respiratory muscles; and 2) to analyze their relationship with the level of respiratory effort.

METHODS: Eight male patients with stable OSAS and eight male normal subjects [age (yr.): 53.8±10.5 and 45.0±7.0 respectively] were in supine position and breathed through a nose mask connected to an external source of a negative pressure whose value decreased -7cm H_2O at 90-second intervals until the subject could no longer breathe, reaching its maximum maintained pressure (MMP). Surface EMG signals were recorded (Ag-AgCl electrodes) from three respiratory muscles: genioglossus (GEN), sternomastoid (SMM) and diaphragm (DIA). EMG signal was full-wave rectified and demodulated with a final sampling freq. of 20 Hz. Baseline trends were removed to guarantee stationarity. Then, signals were normalized and lag-embedded (embedding dim.=3 and emb. lag=first minimum of the autocor. function) and prediction was carried out, using l.o.o. cross validation, at different values of prediction horizon (PH). Evaluation of the fitted function for each selected value of PH is carried out by: 1) computing r^2 statistic for the model; and 2) estimating the size of the residuals. Three parameters were calculated: R07norm (PH where the r^2 statistic goes under 70% normalized with respect to respiratory period); Rp (r^2 value around PH corresponding to half a respiratory period) and LogPT (error at PH to infinity). For every subject, values of each parameter were obtained. Examples of functions and parameters are shown in the Figure.

RESULTS: R07norm increases with the level of effort in mean values for all the muscles, and this increment is statistically significant for GEN and SMM (p-value<0.04). In many cases, r^2 statistic decreases initially with PH, but shows higher values at PH corresponding to the half respiratory period. These values

increase with the level of effort (linear trend statistically significant for SMM, p-value<0.01). LogPT decreases in general in mean values with higher efforts, and this linear trend is statistically significant for SMM (p-value<0.03). All of these preliminary results are found in both populations.



Examples of: (a) r^2 statistic as a function of PH and its associated parameters; (b) estimation of the residuals (mean of the logarithm of the absolute value of the residuals) as a function of PH and parameter logPT

CONCLUSIONS: Nonlinear prediction is a useful technique for the evaluation of respiratory muscles function, i.e. GEN and SMM. The initial decrement of r^2 statistic with PH corresponds to a deterministic behavior and the model predictions are reasonably good at half respiratory period (especially at higher levels of effort). All parameters show this clear dependence on the level of respiratory effort.

SENSITIVITIES OF WEIGHT DISCRIMINATION TASK, ELECTROMYOGRAM AND MECHANOMYOGRAM IN GRIP EXERCISE

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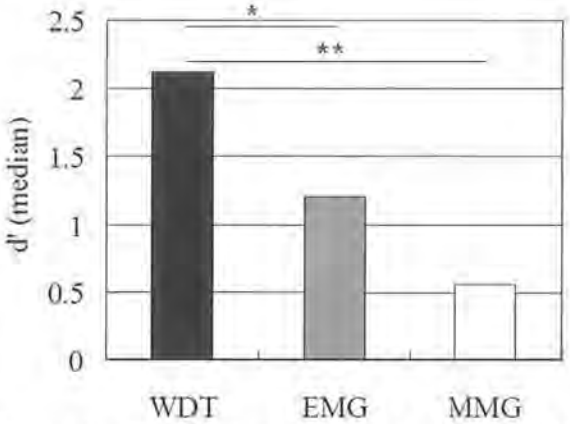
AIMS: An electrical activity and a mechanical activity of muscle obtained by an electromyogram (EMG) and mechanomyogram (MMG) recordings are often used to evaluate a state of muscle. Although the weight discrimination task (WDT) in psychophysical measurement is conventional method to evaluate sensitivities of the heaviness perception, no attempt has been made to compare sensitivities among these measurements.
The aim of this study was to compare these sensitivities. We simultaneously measured sensitivities in grip exercise for WDT, for EMG and for recordings.
METHODS: Healthy three women and five men (ranging:21~27 years) participated in the experiment. Subjects sat on a chair and their preferred hand was placed on a grip apparatus. The WDT, EMG and MMG were measured simultaneously in grip exercise. In the weight discrimination task subjects had to compare two different weights that were standard weight and test weight, respectively and had to answer which weight was heavier (Two-Alternative-Forced Choice: 2AFC). We used one standard weight (4.6 kg) and nine test weights ranging from 3.0 to 6.2 kg. Each test consists of 20 trials.
In the EMG recordings, Ag/AgCl surface electrodes with a diameter of 0.9 cm, was fixed over the flexor-digitorum-superficialis muscle. EMG signals were amplified by Neuropack® (NIHON KODEN) with a bandwidth of 10 Hz to 1 kHz.
In the MMG recordings, we used a uniaxial accelerometer (model MP110-10-101; Medisens, Japan) with a rectangular prism (a base of 9 mm×9 mm, a height of 5 mm and a mass of 0.75 g). The accelerometer was attached over the belly of the flexor-digitorum-superficialis muscle with a double-sided adhesive tape. The MMG signals were amplified and filtered with a bandwidth of 1 to 250 Hz (model MPS110; Medisens, Japan). The amplified EMG and MMG signals were digitized at the sampling rate of 2 kHz (Maclab, AD Instruments) and fed into a computer. We used d' in signal detection theory as an index to compare WDT directly with those in EMG and MMG recordings.
RESULTS: We used the Wilcoxon signed-rank test to analyze the data obtained from the three measurements. The d' shows power of the test to find a difference in between the standard weight and the test weight. The results showed that the d' was 2.12 for WDT, 1.20 for EMG and 0.55 for MMG when we chose the test weight of 5.0 kg (Figure). The d' in the WDT was significantly larger than those in the EMG and MMG recordings ($p<0.03$ and $p<0.01$).
CONCLUSIONS: We conclude that the WDT could be a good measurement as well as the EMG and the MMG to evaluate the state of muscle.



Comparison of the sensitivittes between weights of 4.6 and 5.0 kg weights in three measurements. The d' in WDT was significantly larger. (: p<0.03, **: p<0.01)*

MYOELECTRIC SIGNAL CLASSIFICATION FOR PHONEME BASED SPEECH RECOGNITION

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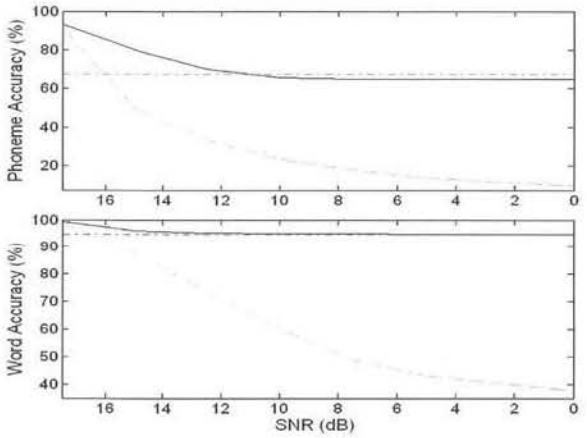
AIMS: Traditional acoustic speech recognition accuracies have been shown to deteriorate rapidly in high noise environments. In this work a secondary information source is exploited using myoelectric signals (MES) collected from five facial articulatory muscles during speech. Words are classified at the phoneme level using a hidden Markov model (HMM) classifier.
METHODS: Myoelectric and acoustic data were collected from four subjects while speaking a ten word vocabulary (the words 'zero' through 'nine'). The acoustic data was segmented offline into its phonemic composition. A time-shifted version (allowing for acoustic-MES delay) of this segmentation was then applied to the corresponding MES. Feature sets consisting of the first 12 Mel-frequency cepstral coefficients and RMS value were extracted and classified using a 5 state left-to-right HMM. Phoneme classifications were then combined to produce a word decision. Classification performance was measured in the presence of varying levels of simulated white Gaussian noise. Results were compared to previously found word-based MES recognition [1].
RESULTS: Acoustic classification rates, while over 99% at low noise levels, dropped significantly as signal-to-noise ratios approached 0 dB. A MES word classification accuracy of almost 95% (using an optimal acoustic-MES delay of 100ms) remained constant across noise levels. A combined multi-expert system obtained word accuracies nearing 100% at low noise levels, converging to the MES accuracy at high noise levels.
CONCLUSIONS: It has been shown that significant information exists at the phoneme level in facial MES. This information can be used to classify speech with high accuracy in levels of noise which render conventional acoustic classification unfeasible. A multi-expert system was shown to outperform the acoustic classifier at all noise levels. Phoneme based word recognition improved upon previously reported word based recognition rates by nearly 10%.



Accuracy versus SNR

[1] Chan ADC , Englehart K, Hudgins B, Lovely DF. "Hidden Markov Model Classification of Myoelectric Signals in Speech" in Proceedings of the 23rd Annual IEEE/EMBS Conference, 2001.

ADVANCED EMG AMPLITUDE PROCESSING USED IN CONSTANT-FORCE EMG-TORQUE ESTIMATION

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AIMS: Advanced EMG amplitute (EMGamp) processors that incorporate signal whitening and multiple-channel combination have been shown to improve EMGamp estimation significantly. In this study, we compared the performance of EMG-torque estimators with and without these recent EMGamp processors.
METHODS: Fifteen healthy subjects (eight male, seven female) produced constant-posture, nonfatiguing, force-varying contractions about the elbow while torque and biceps/triceps EMG were recorded. Four biceps and four triceps EMGs were acquired using conventional bipolar electrode-amplifiers. EMGamp was related to torque using a linear FIR model in which total joint torque was formed from a flexion torque contribution (related to biceps EMGamp) subtracted from an extension torque contribution (related to triceps EMGamp). EMGamp was estimated in four manners: 1) single channel, unwhitened, 2) single channel, whitened, 3) multiple channel, unwhitened and 4) multiple channel, whitened.
RESULTS: As shown in the Figure, both whitening and multiple-channel combination reduced EMG-torque errors and their combination provided an additive benefit. Using a 15th-order linear FIR model, EMG-torque errors with a four-channel, whitened processor averaged 7.3% of maximum voluntary contraction (or 78% of variance accounted for). By comparison, the equivalent single-channel, unwhitened (conventional) processor produced an average error of 9.9% of maximum voluntary contraction (variance accounted for of 55%).
CONCLUSIONS: It was hypothesized that higher fidelity (i.e., lower noise) EMGamp processing would reduce the errors in EMG-torque prediction. Our results show that both EMG signal whitening and multiple channel combination - methods previously shown to improve EMGamp estimates - lead to reduced EMG-torque prediction errors. The lowest errors result when the two techniques are used in combination.

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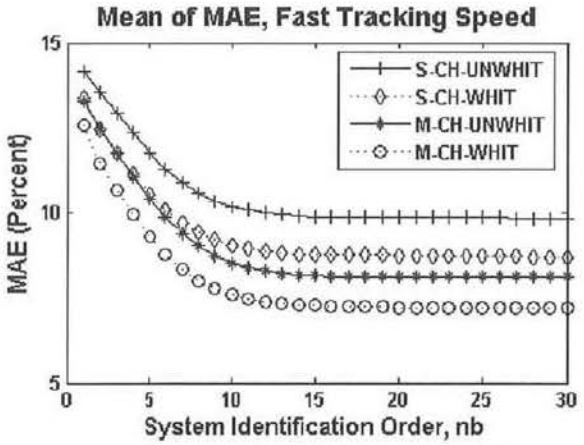

Mean values of mean absolute error (MAE) results, as a function of the system identification model order, for each of the four EMGamp processors. All errors normalized to twice the torque at 50% flexion MVC. Each value in each plot is the average of 180 test recordings

T02.P01
IDENTIFICATION OF NON-PROPAGATING COMPONENTS IN SURFACE EMG RECORDINGS BY OPTIMAL SPATIAL FILTERING

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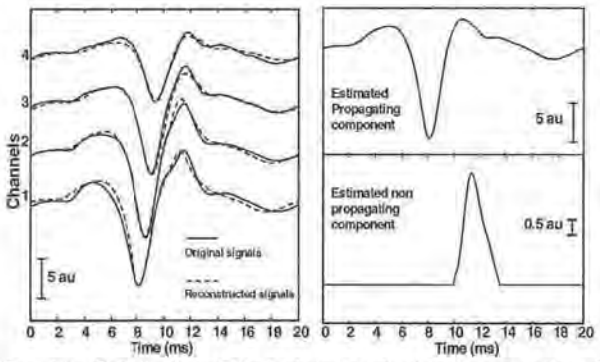
AIMS: A new method for the estimation of muscle fibre conduction (CV) from surface EMG signals is proposed, reducing the effect of non-propagating components.
METHODS: Surface EMG signal is modelled as the sum of a propagating and a non-propagating component. The propagating component is assumed to travel without distortion across channels. The non-propagating component is assumed to have the same shape but different amplitude across channels. Given a pair of spatial filters obtained from 4 detection channels, CV was estimated by the optimal compensation of the spatial filter transfer functions with equivalent temporal filters (with transfer functions of the same shape as the spatial filters) dependent on the delay of propagation to be estimated. Only pair of spatial filters with vanishing weights were considered (resulting to two degrees of freedom). Each filter pair provides a different estimation of the delay, depending on how the non-propagating components are reduced by the spatial filters. The optimal filter pair (to be determined) annihilates the non-propagating components. Imposing this condition, a method to estimate propagating and non-propagating components was developed. The choice of the optimal filter pair was based on the accuracy in reconstructing the input signals by the sum of the estimated propagating and non-propagating components.
RESULTS: The new method was applied to simulated and experimental EMG signals (Figure). Simulated signals were generated by a cylindrical, layered volume conductor model. Experimental signals were recorded from the abductor pollicis brevis with a linear array of 16 electrodes. In the simulations, the proposed approach provided CV estimates with lower bias due to non-propagating signal components than previously proposed methods (simulated value 4 m/s): 3.92±0.3 m/s (proposed method); 5.1±1.2 m/s (spectral matching method); 4.4±0.9 m/s (reference points). In experimental signals, the technique separated propagating and non-propagating signal components with an average reconstruction error of 2.9±0.9% of the signal energy.



Example of application of the proposed method to the separation of propagating and non-propagating components from experimental monopolar single motor unit recordings (abductor pollicis muscle).

CONCLUSIONS: A new method for CV estimation is proposed. The technique is applicable to signals with one propagating and one non-propagating component (single motor unit action potentials). The determination of the optimal filters also allows the separation of the propagating and non-propagating signal components. The technique may find application in single motor unit studies for decreasing the variability and bias of CV estimates due to the presence and different weights of non-propagating components.

T02.P02
SEPARATION OF PROPAGATING AND NON-PROPAGATING COMPONENTS IN SURFACE EMG

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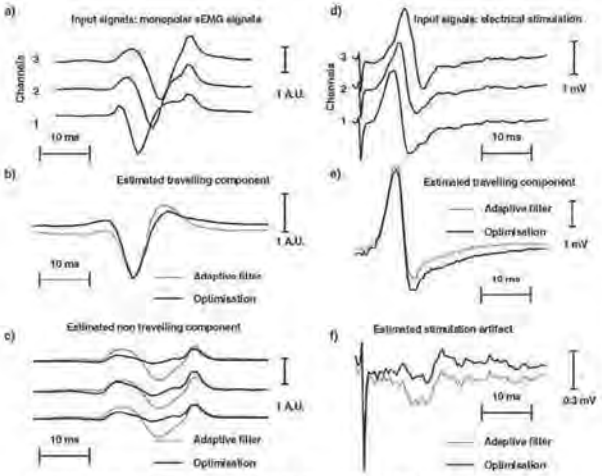
AIMS: Surface electromyogram (EMG) detected by electrode arrays along muscle fibre direction can be approximated by the sum of propagating (across channels) and non-propagating components. A technique to separate propagating and non-propagating components in surface EMG signals is developed. The method is applicable to signals with one propagating and one non-propagating component.
METHODS: The method is based on two steps: the first is an adaptive filter, which allows to obtain an estimation of the delay between signals detected at different channels and a first estimate of the travelling and non-travelling components; the second step is based on a regularisation method and is used to optimise the estimation of the two components. The method was optimised on simulated signals, and then applied to single motor unit action potentials (MUAP) and to M-waves.
RESULTS: The new method was first tested on synthetic signals constituted by the sum of a propagating and a non-propagating signals and then applied to simulated and experimental EMG signals. Simulated signals were generated by a cylindrical, layered volume conductor model. Experimental signals were monopolar surface EMG signals collected from the abductor pollicis brevis muscle and M-waves recorded during transcutaneous electrical stimulation of the biceps muscle.
CONCLUSIONS: The main contribution to non-propagating components in a MUAP is given by the generation and the extinction of the transmembrane current travelling along the fibres. The automatic identification of such non-propagating components is useful for both estimating anatomical features (position of the innervation zone and tendons) and to decrease bias in conduction velocity (CV) estimation. In the case of M-waves, the main non-propagating component is the stimulation artifact, in addition to those mentioned above. The technique may find different applications: in single motor unit (MU) studies, for decreasing the variability and bias of CV estimates due to the presence of the non-propagating components or for detecting automatically the position of the innervation zone and of a tendon; in processing M-waves, it could be useful to remove the stimulation artifact.



Application to three monopolar surface EMG signals, a), b), c), collected from the abductor pollicis brevis muscle.
Application to a surface EMG signal recorded during transcutaneous electrical stimulation of the biceps brachii muscle, d), e), f).

T02.P03
ESTIMATION OF MOTOR UNIT CONDUCTION VELOCITY DISTRIBUTION BY MULTI-CHANNEL M-WAVE DECONVOLUTION

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AIMS: We propose a method for estimating the distribution of motor unit conduction velocity (CV) from M-waves recorded with a linear electrode array.
METHODS: An M-wave was modelled as the summation of delayed and scaled (in amplitude) versions of the same waveform. Thus, the compound potential can be related to the single action potential by a convolution operation. Neglecting the spread of the end-plates, the delay associated to the detection of each action potential is inversely related to its velocity of propagation. The determination of the distribution of the delays given the M-wave can be obtained by the inversion of the convolution operator applied to the single action potential to obtain the M-wave (deconvolution). Deconvolution is an ill-posed problem which requires the use of a regularisation technique. Tikonov regularisation method was used in this study. The method was generalised to the case of a multi-channel detection system. The estimated solution was obtained by minimising, in the least square sense, the error in the reconstruction of the data. Both penalisation of L_2 norm of the solution and of its derivative were tested. Furthermore, an algorithm for imposing positivity of the solution was implemented, based on Landweber iteration method. The resulting delay distribution was finally restricted to physiological delays. The regularisation parameters were chosen by the L-curve method.
RESULTS: The developed method was applied to simulated (with multi-layer, cylindrical description of the volume conductor) and experimental signals (from transcutaneous electrical stimulation of the biceps brachii muscle). The method proved to be sensitive to changes in the standard deviation of the CV distribution (Figure A) in simulated signals, although the estimates presented a bias, especially for low standard deviation values. Figure B shows the application of the method to representative experimental signals.
CONCLUSIONS: A M-wave deconvolution method was developed generalising Tikonov regularisation to a multi-channel detection system. The method may detect relative changes in the spread of conduction velocity of the motor units and can thus be applied in fatigue studies.

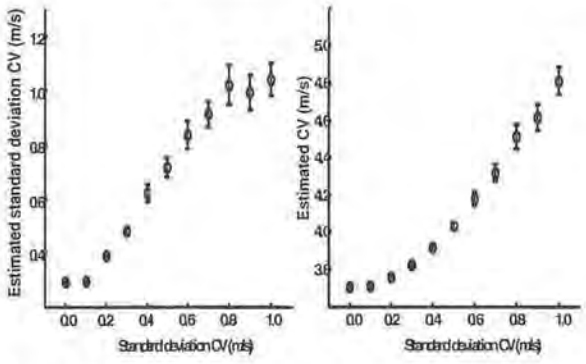

Figure A) Results on simulated signals. Estimated standard deviation and mean CV (average±SD, over 100 simulations) as a function of the standard deviation imposed in the model.

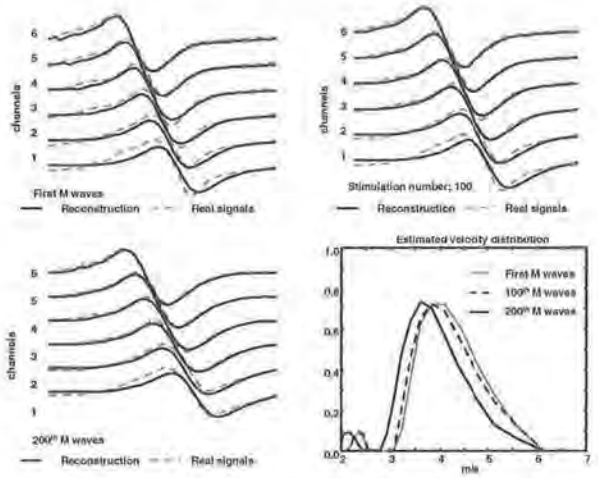

Figure B) Example of application to experimental signals

T02.P04
ASSESSMENT OF STABILITY OF PERIODIC MUSCLE CONTROL IN RUNNING BY PULSE COUNTING PROCESSING OF ELECTROMYOGRAM

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AIMS: In this study, stability of periodic muscle control in running was assessed by degree of variation of the cyclic pattern of each stride obtained by pulse counting processing of electromyogram (hereafter EMG).
METHODS: The material used was the EMG observed by four channel bipolar surface electrodes with 5mmΦ in diameter, which were attached on the soleus muscle of adult male. The action was long distance running on a treadmill with the velocity of 3.6 m/s and stride period of 2/3 sec. The EMG of successive 22 strides was recorded and processed on a PC. In the pulse counting processing, pulses were detected from the EMG and pattern of change in pulse number was derived by 40 ms running time window. The interference waveform was differentiated in order to emphasize peaks preliminary to pulse detection. Degree of the variation of the cyclic pattern was measured by the range of variation of the peak value of the obtained pattern of each stride normalized by the average, and the coefficient of variation of the pattern. The coefficient was derived by adjusting the phase of the pattern at the center of the section where the amplitude was more than 20% of the peak value of the average pattern, summing the standard deviation of the pattern at each time point, and normalizing it by the area of the average pattern.
RESULTS: The range of variation of the peak value was from -15% to +13%, and the standard deviation was 9% (Figure 1).

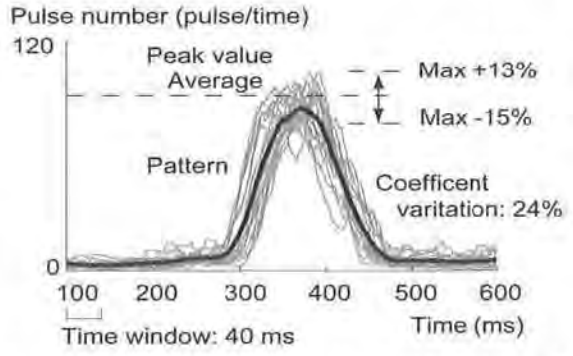

Figure 1: The patterns obtained by pulse counting processing of the EMG in running. Thin line: Each stride; Bold line: The average.

The coefficient of variation of the pattern was 24%. For comparison with the rectifying and smoothing processing which has been widely used, pattern was derived by both side wave rectifying the EMG and smoothing by the running average through 40 ms time window. The range of variation of the peak value and the standard deviation were about twice as large as those of pulse counting processing. The coefficient of variation of the pattern was 1.2 times larger.

CONCLUSIONS: The reason why the variation of the pattern obtained by pulse counting processing was smaller than that of rectifying and smoothing processing was considered that the former suffered less effects of attenuations and interference of motor unit action potentials. The characteristic obtained by the pulse counting processing was higher temporal resolution in rising and falling slopes of the patters. The fact that there were the strides whose patterns corresponded close to each other suggested that this measure of degree of variation indicated the stability of muscle control without the artifacts in the EMG processing.

T02.P05
KNOWLEDGE-BASED AUTOMATIC DECOMPOSITION OF EMG SIGNALS

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AIMS: This paper describes an EMG decomposition program based on EMGLAB [1] that uses expert knowledge to reduce the amount of manual editing needed to achieve full and accurate decomposition of EMG signals.

METHODS: The program has two main stages. First, spikes are detected and clustered using adaptive thresholds and firing-time information as well as shape information. Then the remaining spikes are classified by means of a multi-pass procedure that includes supervised classification, robust template merging using fuzzy systems, resolution of superimpositions, and predictive firing-time insertion.

RESULTS: The accuracy of the program was assessed using synthetic EMG signals of various complexities. The program was able to correctly identify 90% or more of the discharges of 85% of motor units (MUs) with signal-to-noise ratios greater than 1, where the signal-to-noise ratio is defined as the Euclidean distance between the MU and the next most similar MU, divided by the rms signal amplitude.

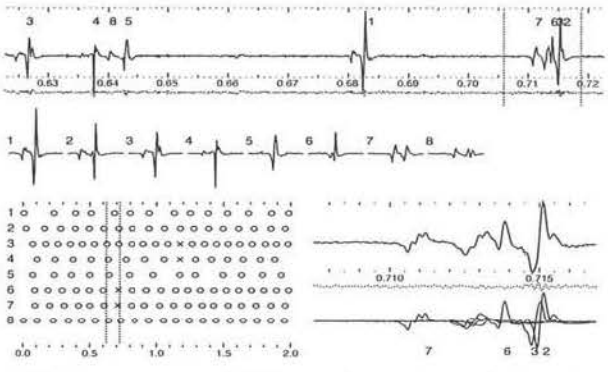

FIG. 1. Decomposition of EMG signal (monopolar-needle-electrode, brachial biceps, normal subject, 10% MVC). Shape-based classification of 2-s signal resulted in incomplete firing patterns (circles). Locations of four missed spikes were predicted and verified by resolving superimpositions (x's).

CONCLUSIONS: The program achieves better performance than standard template matching by using a knowledge-based approach that incorporates rules used by human experts for three important steps: 1) Estimating the correct number of clusters in the clustering stage. The program uses a Mamdani fuzzy system in which the structure is based on linguistic variables and rules and the membership-function parameters are tuned using recursive least squares. 2) Classifying spikes of MUs with similarly shaped templates. The program takes into account not only the two most similar templates but also firing time information. The assignment is performed recursively using expert rules to correct previous errors after new assignments. 3) Filling in gaps in firing patterns resulting from missed identifications. These missed identifications are often due to superimpositions. The program uses a rule-based method to predict the location of missing occurrences and then uses a superimposition-resolution algorithm to verify the location (Fig. 1). These steps reduce the amount of manual editing required to achieve full decomposition.

[1] McGill KC, et al. EMGLAB: An interactive EMG decomposition prog-ram. J Neurosci Meth, 149: 121-133, 2005.

T02.P06
MOTOR UNIT RECRUITMENT IN REFLEXIVELY ACTIVATED MULTIFIDUS MUSCLE OF FELINE MODELS

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AIMS: Determine motor unit (MU) activation pattern and fatigue during reflex activity.

METHODS: An external 40N-tension was applied to the supraspinous ligament of the feline models (divided into 2 experimental groups) for six consecutive trials of 10-min duration. Rest periods of 10 (N=3) or 20 (N=3) minutes were supplied between trials for the 1st and 2nd group, respectively. EMG signals were recorded intramuscularly with bipolar electrodes, inserted in the right L-3/4, L-4/5, L-5/6 multifidus muscles. Signals were band-pass filtered (6-500Hz) and stored with a sampling rate of 1kHz. The EMG signals from each trial were split into 20 portions of 30-s duration. All EMG peaks exceeding 30 μV were detected and the signal portion of 20-ms duration centered around the detected peak was considered as an individual motor unit potential (IMUP). All IMUPs detected from a single EMG portion were averaged to obtain its representative MUP (AvMUP). The number of IMUPs contributing to each AvMUP was defined as activity. The relative (to the 1st portion in 1st trial) changes in a recently proposed index of muscle fatigue (FI_{nsm5}), median frequency (F_{med}) as well as activity were analysed.

RESULTS: The pattern of AvMUP-shape change in the majority of trials suggested initial recruitment of predominantly fast MUs, in which peripheral fatigue was developed and accumulated during the experiment. This presumption was well supported by the relative change in fatigue indices calculated on the basis of AvMUPs. During initial trials FI_{nsm5} increased almost linearly in both protocols. In the next trials relative changes in the index depended on the rest period duration, supposing accumulation of more fatigue in initially activated MUs of the 1st experimental group. In the latter the initial steep increase in FI_{nsm5} was followed by maintaining a relatively constant level (approximately 355%), while FI_{nsm5} increased monotonously during entire trials in the 2nd experimental group. Statistical analysis revealed 3 groups of significantly different data sets (1st, 2nd and the rest of the trials) in 1st experimental group, while only 2 (distinguishing only the 1st trial) in 2nd. Index changes for all trials were well-fitted with a bi-exponential model (r^2>95%). The starting values (representative for the fatigue accumulated during previous trials) for the 2nd trial in short-rest and the 2nd group of trials in long-rest protocols were similar (165%), while that for the 3rd group of trials in short-rest protocol revealed higher initial fatigue level (200%). The changes in F_{med} were similar in pattern, but in the opposite direction and of much lower range (100%-80%).

The level of activity decreased during each trial as well as between consecutive trials. Activity remained relatively higher in the 1st compared to the 2nd experimental group during last trials, suggesting the necessity of more MUs and/or firing at higher rates (therefore low-twitch) for maintaining the required force.

CONCLUSIONS: Faster and powerful MUs are recruited firstly, in order quickly to provide stronger support to the spine. Depending on the applied rest periods, peripheral fatigue might be accumulated, preventing fast MUs from maintaining the required force and causing rise in slow MU activity.

T02.P07
USING TORQUE AND MYOELECTRIC SIGNAL DATA TO EXAMINE THE BILATERAL LIMB DEFICIT PHENOMENON IN FEMALES OF DIFFERENT AGES

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AIMS: The bilateral limb deficit (BLD) describes the difference in maximal or near maximal force generating capacity of muscles when they are contracted alone or in combination with the contralateral muscles (1,2,3). The bilateral limb ratio (BLR) is the measure of the total bilateral force over the total unilateral force produced (1). It has been suggested that a decline in MES, in parallel with force deficit during bilateral contractions would imply a neural basis to the deficit (1). The goal of this study was to examine the presence of the BLD in three age groups of females (adolescent females, adult females and older females) during dynamic knee extensions and quantify the BLR using both torque (BLR_{Torque}) and MES data (BLR_{MES}). The role of antagonist muscle coactivation was also investigated.
METHODS: Twenty-three female subjects from three age groups participated in the study. The older group (n=7) had a mean (±SD) age of 63±6 years, height of 162±6 cm and weight of 70±18 kg. The adult group (n=8) had an age of 31±7 years, a height of 166±6 cm and a weight of 72±12 kg. The adolescent group (n=8) had a mean of 15±1 years, height of 167±5 cm and a weight of 58±6 kg. Torque and MES data were collected during slow (45 deg/sec) isokinetic knee extensions using a dynamometer and an eight-channel bioelectric signal data acquisition system.
RESULTS: Across all subjects it was found that the mean BLR_{Torque} was 74.6±9.8% and the BLR_{MES} was 85.5±37.7%. Individual group data showed that the BLD_{Torque} was 79.5±4.5% for adults, 70.2±12.6% for older adults and 73.6±9.8% for adolescent females. The findings using the MES were less consistent, with adult females showing no MES deficit (BLR_{MES}=103.5±51.8%), while the adolescent and older females demonstrated a BLR_{MES} similar to BLR_{Torque} (BLR_{MES}=72.5±21.9% and BLR_{MES}=79.8±28.9%, respectively). It was found that BLR_{Torque} and BLR_{MES} were correlated (P=0.000) across all subjects and that BLR_{MES} was correlated with antagonist coactivation (P=0.034).
CONCLUSIONS: It was found that a BLD exists during isokinetic knee extensions regardless of age. In additino, a similar BLD was found using either torque or MES data for adolescent and older females, however no BLD was detected using MES data for adult females. There has been little work that has investigated the presence of the BLD in younger subjects such as adolescents and this study found that this population exhibits both a torque and MES deficit during dynamic knee extension.

1. Howard, J.D., and Enoka, R.M., (1991). Max. bil. contractions are modified by neurally mediated interlimb effects. J of Appl. Physiol., 70, 306-316.
2. Jakobi, J. and Chilibeck, P. (2001). Bilateral and unilateral contractions: possible differences in maximal voluntary force. Can. J. of Appl. Physiol 26(1), 12-33.
3. Kuruganti, U., Parker, P., Rickards, J., Sexsmith, J., and Tingley, M. Bil. training reduces bil. leg strength deficit for old &young adults. Eur. J. of Appl. Physiol. 94: 175 - 179.

T02.P08
RELIABILITY OF RECURRENCE ANALYSIS TO EXTRACT SYNCHRONOUS FIRING FROM SURFACE MYOELECTRIC SIGNAL

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AIMS: Information on motor strategies can be extracted from the surface electromyogram (EMG) by nonlinear methods. The percentage of determinism (%DET) obtained from recurrence quantification analysis (RQA) may be a sensitive variable to detect synchronous motor unit behaviour. The purpose of the present study was to validate this methodology by comparing it with an established technique estimating the degree of synchronization of pairs of voluntary activated motor units from the correlation of their firing in the time-domain.
METHODS: Single motor unit activity was recorded in Extensor Carpi Radialis (ECR) muscle by pairs of tungsten microelectrodes inserted into the muscle belly. Cross-correlation analysis was performed in order to determine synchronization peak area by computing synchronous impulse probability. Surface EMG activity was recorded in parallel by electrodes placed over the skin of the same muscle and %DET was used as a measure of synchronous activity.
RESULTS: The %DET appeared to be a valid measure of synchronization yielding results comparable to those obtained with cross-correlation analysis. Increases in %DET ($t=64.59$, $P<0.0001$) highly correlated ($r^2=0.70$, $P=0.0013$) with pharmacologically-induced increases in the synchronization activity of pairs of ECR motor units ($t= 8.71$, $P<0.0001$).
CONCLUSIONS: RQA may be used as an alternative methodology for testing synchronous motor unit behaviour from surface EMG under physiological and pathological conditions.

T02.P09
STREAMING TOPOGRAPHIC MAPPING OF LUMBAR MYOELECTRIC ACTIVITIES

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AIMS: To evaluate the feasibility of streaming topography as a diagnostic tool and to investigate the lumbar muscular coordination processes associate with different clinical conditions in people with and without low back pain.
METHODS: Lumbar myoelectric activities were measured by surface electromyography (sEMG) electrodes array during flexion/extension movement. Root mean square value of sEMG signals amplitude were calculated as a function of both position and time. Progression of surface myoelectric potential distribution were presented in a form of streaming topographic video. On instantaneous topographic map, points of equal potential are joined together into contours. Colour scale are used to represent the contour level. 10 healthy subjects (without back pain in past 2 years) were recruited to characterise the normal pattern of dynamic lumbar muscle activation strategy. In addition, a preliminary clinical study was conducted on 5 chronic low back pain (LBP) patients.
RESULTS: For healthy subjects, a consistent, reproducible and reliable activation pattern was revealed by the streaming topography. Under flexion-extension, the recruitment of lumbar musculature is symmetric, with high intensity shown in mid l5 region during phases of flexion and postural holding. During extension phase of the action. a gradual sequential increase in activation intensity was found from mid l5 to l3 region. This muscle activation pattern in streaming topography was seen consistently in 9 out of 10 normal subjects. In clinical observation, activation pattern of lbp patients observed from streaming topography was obviously different from that of normal subjects. All the 5 LBP patients, more or less, showed abnormal and asymmetric patterns.

CONCLUSIONS: Streaming topographic mapping technique potentially uncover the complex interaction of different lumbar muscle compartments within a dynamic motion. Evolution of lumbar myoelectric activities can be followed over short epoch of time, making it possible to follow the global motor control strategies along the dynamic motion. Assessment of muscular coordination processes and location of deviations and abnormalities relating to the functional aspects of the investigated lumbar musculature was made easy and objective by this novel technique. A more comprehensive evaluation on global dynamic muscular activities in lumbar region is provided. This novel technique would possibly improve the clinical management of LBP.

Series of streaming topographies of normal subjects under flexion-extension.
From left to right: 1) flexion, 2) postural holding, 3) extension

T02.P10
EVALUATION OF INFLUENCE OF ECG INTERFERENCE ON SEMG ASSESSMENT OF LOW BACK MUSCLES

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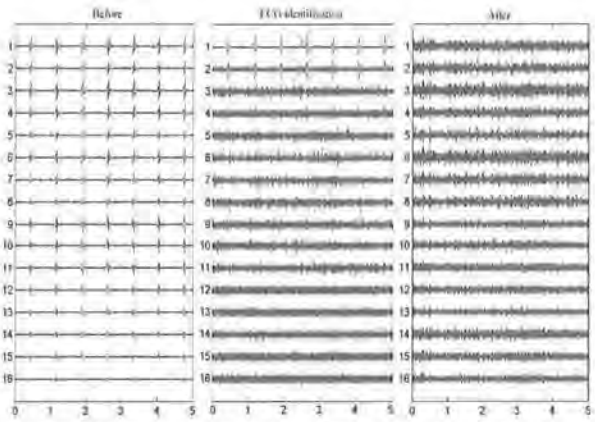
AIMS: This study aims to evaluate the relative effect of ECG interference on back muscles sEMG parameters and their sensitivity on low back pain (LBP) assessment.
METHODS: Surface EMG measurements on paraspinal muscles from normal and LBP patients before and after ECG noise cancellation were compared. 16 channels Surface EMG was recorded from low back muscles of 10 healthy and 10 chronic IBP patients during sitting, standing, and flexion-extension action. ECG cancellation was performed by independent component analysis (ICA) technique. Median frequency (MF) and root-mean-square (RMS) were calculated in the raw and denoised sEMG of paraspinal channels respectively. Effect of ECG interference on low back semg was evaluated by comparing the MF and RMS between raw and denoised results in healthy and LBP groups. Moreover, differences of RMS and MF between LBP and healthy group were compared for both raw and denoised results to study the effect of ECG on sEMG assessment sensitivity
RESULTS: Significant RMS decreases ($p<0.05$) and MF increases ($p<0.05$) were founded after ECG noise removal in all actions. After ECG noise removal, MF and RMS of sEMG showed larger difference in static actions than in dynamic action, implyiing the corruption of sEMG signal to be more serious and prominent during static actions than that in dynamic test. For LBP assessment sensitivity, improvements in discriminative ability were seen in MF parameter during sitting (difference between normal and patient increase from: Left: 8 to 45 Hz; Right 11 to 53 Hz) and extension (difference between normal and patient increase from: Left: 11 to 15 Hz; Right 16 to 20 Hz) respectively.
CONCLUSIONS: ECG interference showed significantly influence on the sEMG measurements in both the normal subjects and LBP patients. The influence of ECG noise may produce distortion in lumbar muscle sEMG measurement and interpretation. Thus, cancellation of ECG interference is imperative in order to improve the sensitivity of LBP assessment. The present study provides a more complete understanding on the missing information of relative effect of ECG interference on sEMG measurements of low back muscles.



Sixteen channels of back muscle sEMG signals recorded from a normal subject during upright standing: (a) before, (b) under and (c) after ECG cancellation. All the plottings of EMG signals are under auto-scaling.

T02.P11
RESOLUTION OF SUPERIMPOSED MUAPS WITH A GENETIC ALGORITHM

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AIMS: The activity of many motor units (MUs) is required to produce a muscular contraction of high level. The MU firing is then asynchronous and when needle electrodes are used to record their activity, a number of overlapping motor unit action potentials (MUAPs) are observed. While partial superimpositions can be resolved easily using template matching, only few algorithms are able to resolve complete superimpositions, especially destructive interference, involving an arbitrary number of MUAPs of unknown identities [1]. We present a hybrid genetic algorithm (GA) aimed at resolving complex overlapping potentials that cannot be usually resolved with template-matching-based methods.
METHODS: The initial set of trial alignments consists of the attempts where template matching coupled with an exhaustive set of MUAP combinations that produce either constructive or destructive interference were unsuccessful. With a GA, individual solutions will interact according to well-defined probabilistic rules in order to ultimately evolve towards a small population of trial alignments that have a good fit to the superimposed waveform. The cost function is chosen for better specificity of the alignment of both the reconstructed waveform and of the individual MUAPs. To increase the likelihood of reaching a global optimum, the stochastic GA is combined with a deterministic gradient descent method, thus yielding a hybrid optimization scheme.
RESULTS: The proposed method was initially tested on simulated signals made of 12 MUAP trains and where the density could reach up to 300 MUAPs/s. Decomposition of such complex signals yielded accuracy rates better than 90%, with the hybrid GA accounting for up to 5% of the identifications. The hybrid GA was also tested on 300 simulated superimpositions of MUAPs obtained from fine wire recordings of the biceps brachii of normal subjects. Unsolved with template matching, a solution was found for more than 99% of these superimpositions by involving 2 to 4 MUAPs, when the actual number of MUAPs involved as well as their identities remained unknown. The 99% accuracy rate dropped significantly in absence of the gradient descent adjunct, thus confirming its usefulness. The time needed for each resolution was approx. 5 s on a recent desktop computer.
CONCLUSIONS: The hybrid GA appears to be able to resolve complex superimpositions involving an arbitrary number of MUAPs of unknown identities with a high degree of confidence. The technique's most attractive feature is its ease of

implementation. Its main drawback is the relatively lengthy processing time required to resolve superimpositions but work is under way to improve this matter. The resolution technique is an add-on to a program that can now decompose one-channel EMG recordings of densities higher than any other software we are aware of [2].

[1] K.C. McGill, "Optimal Resolution of Superimposed Action Potentials," IEEE Trans. Biomed. Eng., vol. 49, pp. 640-650, 2002.
[2] J.R. Florestal, P.A. Mathieu and A. Malanda, "Automated Decomposition of Intramuscular Electromyographic Signals," IEEE Trans. Biomed. Eng., Accepted for publication.

T02.P12
EFFECTS OF EMG PROCESSING ON BIOMECHANICAL MODEL OF MUSCLE JOINT SYSTEMS

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AIMS: The aim of this study was to determine how surface EMG processing (high-pass filtering (HP) and whitening) affects outcomes of a biomechanical model of a muscle joint system of the trunk region. Model outcomes comprise estimated muscle moments, peak joint contact forces, and joint stability.
METHODS: Nine healthy male subjects performed 3 isometric trunk extensions, with the pelvis and the upper body strapped against a frame. Extension force had a pyramidalshaped pattern, starting at rest to maximum contraction and back to rest again. Trunk extension moments and surface EMG of 9 unilateral trunk muscles were measured. Raw EMG-signals were HP filtered at cut-off frequencies ranging from 10-400 Hz or adaptively whitened. Subsequently, signals were rectified, smoothed and normalized, and used as input to a biomechanical model of the trunk estimating extension moment, peak joint contact forces, and joint stability. Goodness of fit of the estimated trunk muscle moment (Mmusc) to the external measured moment (Mext) was quantified with three measures: 1) root mean square difference between Mmusc and Mext (RMSD), 2) correlation (r) and 3) residual root mean square around a 2nd order polynomial fit (delta). A repeated measures one-way ANOVA was used (α=0.05).
RESULTS: Muscle-moment estimates improved on all three measures with increasing HP frequencies. RMSD decreased by about 13%, r-values indicated a more linear relationship between Mmusc and Mext, and delta decreased by about 36%. Peak contact forces were not significantly affected by HP (p=0.45), but showed a significant decrease of the within-subject standard deviation over repeated exertions (p<0.01). Predicted joint-stability was affected (p<0.01), with higher stability for high cut-off frequencies and a continuous reduction in between-subject standard deviation (60%).

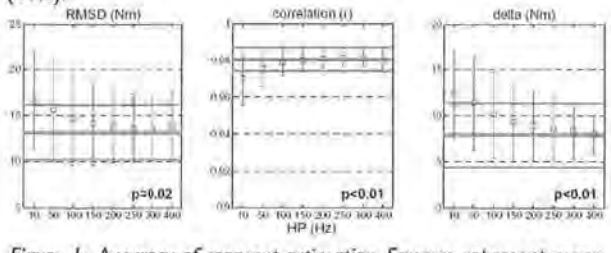

Figure 1: Accuracy of moment estimation. Squares represent mean effects of HP filtering (with error bars indicating SD). Grey lines indicate effect of whitening and its standard deviation.

CONCLUSIONS: HP filtering and whitening of surface EMG signals, used as inputs to a of muscle joint model, had substantial effects on model outcomes. The results suggest that HP filtering and whitening enhance the relative contribution of deeper motor units, in line with theoretical predictions (Dimitrova, JEK 2002). This likely explains the effects on stability that were found. Depending on the physiological crosssection of the underlying muscle crosstalk may become a problematic issue, though not much so in terms of overall model performace, such as in the present study. Compared to whitening, HP has additional benefits of computational efficiency and of a complete removal of ECG contamination.

T02.P13
MUAP DURATION ALGORITHM BASED ON THE WAVELET AND HILBERT TRANSFORMS

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AIMS: We have devised a new algorithm for the automatic measurement of motor unit action potential (MUAP) duration, based on the Discrete Wavelet and Hilbert transforms (DWT and HT) that provides better performance than previous automatic approaches [1].
METHODS: For our study we used a set of 240 50-ms-long MUAPs, sampled at 25.6 kHz, obtained from 8 tibialis anterior (TA) muscles and 88 MUAPs from 8 first dorsal interosseous (FDI) muscles. These MUAPs were wavelet transformed. By selecting the wavelet scale containing most energy, low and high frequency noise was put aside. HT was then applied for finding the envelope of this DWT scale. The initial and final points of the MUAPs were then estimated by using amplitude and slope criteria applied on both the HT and the original signals (both normalized). Duration was then measured as the time interval between the initial and final points. Two expert neurophysiologists carried out 3 independent manual measurements for the initial and end points of the MUAPs in the signal set, establishing a gold standard of the duration marker positions (GSP).
An algorithm referred as Aalborg method (AM) [1], which gave the best results in a previous comparative study [2], was compared to our new Wavelet-Hilbert-based method (WHM).
RESULTS: The mean of the differences between the positions of both methods and the GSP (i.e., the bias of each method), together with the standard deviation (SD) of such differences (the precision) for the start and end points, are given in Table 1. In all cases our new method shows lower values for mean and SD, reflecting a more precise and accurate behaviour. The confidence intervals of the differences (also in Table 1) illustrate that our method is less biased around the GSP (zero is included in half of the cases).
CONCLUSIONS: The new WHM method renders more accurate MUAP duration measurements and and with lower variance than previous automatic algorithms.

Muscle/Method		AM	WHM
TA (n = 152)	Start	2,4 / 5,6 / 1,5 - 3,3*	-0.3 / 1.8 / -0.6 - 0.0*
	End	-1,7 / 5,9 / -2.6 - -0,7	0.3 / 3.3 / -0.1 - 0.9
FDI (n = 88)	Start	2,6 / 6,7 / 1,2 - 4,0*	0,5 / 1,43/ 0,2 - 0,8*
	End	-1,9 / 5,8 / -3,1 - -0,61*	-0,7 / 2,0 / -1,2 - 0,3*

*Table1. Mean/SD/95% confidence interval (ms). *(p<0.01; t test).*

[1] Stålberg, E; Andreassen, S; Falck, B; Lang, H; Rosenfalk, A; Trojaborg, W. "Quantitative Analysis of Individual Motor Unit Potenctials: A Proposition for Standarized Terminology and Criteria for Measurement". Journal of Clinical Neurophysiology 1986; Vol. 3, n° 4:313-348.
[2] Gila L, Gurtubay IG, Rodríguez I, Gómez S, Mallor F, Malanda A, Rodríguez J, Navallas J. Variabilidad en las medidas manuales y automáticas de la duración del potencial de acción de unidad motora. Rev Neurol 2004;39:1083-1084.

T02.P14
PROCESSING TO IMPROVE EMG-BASED FORCE ESTIMATES FROM FATIGUED MUSCLES

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AIMS: Surface EMG (sEMG) amplitudes have been shown to increase during fatiguing, isometric, isotonic muscular efforts [1]. Recently, improved EMG-force relationships have been shown with EMG whitening or when filtering out almost all of raw EMG's low frequency component [2]. This study tested the hypothesis that whitening and high pass filtering will improve the EMG-force relationship as muscles fatigue. Previoulsy, EMG-based muscle force predictions have been contaminated during fatiguing tasks, as it was not possible to discern if EMG amplitude increases reflected force increases or only effort increases in tandem with decreasing force generating capacity.
METHODS: Nineteen males participated in the study and 13 were used in this analysis (25.8±7.9 years, 83.6±16.4 kg, 1.77±0.12 m). sEMG signals were recorded from the biceps brachii, brachioradials and triceps brachii. Subjects resisted forces with their elbow at 90° and arm parallel to the table. Elbow moment was monitored with a force transducer placed in series with a cable securing the wrist. Isometric MVEs were recorded and 40% MVE forces were maintained during prolonged,isometric fatiguing trials to exhaustion. sEMG data were processed at 1024Hz and biceps brachii raw signals were whitened as well as high pass filtered (1st order) with 10 different cutoffs frequencies (HPFCs) ranging from 20 Hz (used as a current standard) and 50 to 450 Hz, in increments of 50 Hz. sEMG signal were then full wave rectified, normalized to that signal's MVE maximum and low pass filtered (1.5 Hz). For each of the 11 processing conditions, sEMG signals were fit with a linear regression to estimate the amplitudes at the start and end of the fatiguing trial and determine the relative change (ratio=end/start) over the exhaustive trial. Six of the 19 subjects were excluded, as they demonstrated more than a 10% MVE increase in tricepts sEMG, reflecting potential increases in cocontraction. It was assumed, for the remaining 13 subjects, that biceps force did not change appreciably during the fatiguing trials.

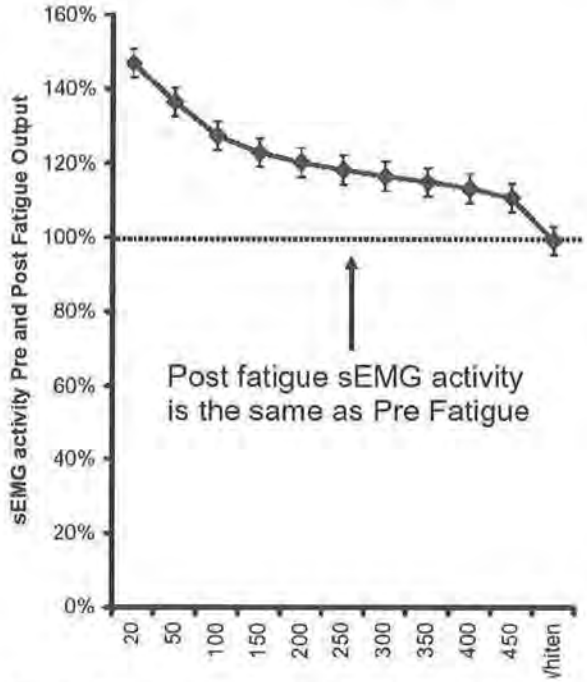

Figure 1. Changes in end/start ratios with whitening and high pass filtering (n=13). (St Err bar)

RESULTS: ANOVA revealed there were significant effects of HPFC. At 20Hz, the fatigued biceps sEMG ratio was 147% (Figure 1) and this ratio steadily declined to 111% at 450 Hz. In general, whitening had the ratio closest to 100% and was significantly lower than all HPFCs. HPFC=450 Hz was lower than all cutoffs at, and below, 150 Hz.
CONCLUSIONS: Potvin and Brown [2] showed that whitening or high pass filtering (HPFC=410 Hz) both improved the relationship between sEMG and muscle force.The current results indicate that this type of processing may also maintaing the sEMG-force relationship better during prolonged, fatiguing, isometric contractions. It is possible that simple processing techniques can be used to remove the fatigue induced artifact in sEMG, such that muscle force prections can be made with more accuracy during fatiguing tasks.

[1] Petrofsky et al, 1982, Ergonomics, 25, 3:213-223
[2] Potvin and Brown, 2004 JEK, 14:389-399

T02.P15
ANALYSIS OF REGRESSION STRAIGHT LINE ANGLE DISPLACEMENT IN RELATION BETWEEN SURFACE ELECTROMYOGRAM AND JOINT TORQUE

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AIMS: We investigated a method for evaluating muscle activities by utilizing regression curve between articular torque and muscle activities relationship. In the present study with attention focused on extension of the knee, the regression straight line was calculated respectively, less than 50% of the maximum output and above, and the relation between the electromyogram derived from Rectus femoris and Vastus medialis and the progress torque, and whether this angle displacement of two straight lines was influenced by the little change in the leg articulatio coxae was analyzed. In the investigation, we aim to determine whether the difference of the muscle activity by the leg position change was possible by confirming the change in the recurrence straight line angle, after having confirmed reliability of the angle displacement calculated by this research.
METHODS: The subjects were 10 healthy individuals. Surface electrodes were applied to the following sites: the RF (i.e., the center of a straight line connecting the iliaca anterior inferior with the upper margin of the patella) and the VM (i.e., the position of the movement of the length, which was obtained by dividing the circumference of the thigh in 20 equal parts, medial to the thigh superior to the patella 1/4 of a straight line connecting the iliaca anterior inferior with the upper margin of the patella). The electrodes were discs, each of which was 10 mm in diameter, manufactured with Ag/AgCl. The inter-electrode length was 15 mm, and the data were recorded according to Double Differential. As EMG data, root mean square (RMS) was calculated in 100 msec. unit. The data on torque were measured with Biodex. Extremity positions on the measurements were a 90° flexed position of the knee joint with the hip joint in the 90° flexed position and that with the hip joint in the 0° flexed position. Visual feedback was utilized with isometric contraction for the measurement, which was changed by stages from 20%, i.e., the maximum voluntary contraction (MVC), to 80%. The procedure for the analysis was as follows: 1) Data were recorded twice on different days in each of the 10 subjects; 2) The relation between recorded torque and RMS was calculated, and the angle change of each electrode of the regression straight line in about 50% in the maximum torque was calculated; 3) The reliability of the angle difference was examined by intraclass correlation coefficient, ICC (1,1); 4)the influence of individual difference, muscle, and extremity positions on the angle difference were assessed by analysis of variance (ANOVA).
RESULTS: As a result of the analysis, ICC values for the RF were 0.66 and 0.69 in flexed and extended positions, respectively, of the hip joint. The VM were 0.19 and 0.56. Only values of RF showed fair reliability of the angle difference. As for the analysis of the influence of angle difference on muscles and extremity

positions of the hip joint, the mean angle difference for the RF was 2.35 degree (SD14.21) in a flexed position and 11.82 degree (SD8.87) in an extended position. As a result of ANOVA, there was a statistically significant difference in the angle difference for the RF between the positions of the hip joint.

CONCLUSIONS: From the research at this time, the angle difference of the regression straight line about 50% was shown to have reliability which was able to validate the analysis as a measurement value. The relationship between changes in extremity position and the regression straight line angle was also analyzed, and the difference of position was reflected by the angle difference of the regression straight line. Thus, we think the possibility of this analytical method becomes the evaluation index of muscle activity characteristic has been shown.

T02.P16
MUSCLE ACTIVITY DURING APPROACH RUN OF SKI JUMPING IN TERMS OF POSTURE CONTROL

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4) Chukyou University, School of health and sport sciences

AIMS: In sports competition, whether victory or not is governed by controlling cooperative muscle activity and explosive muscle force. In ski jumping, posture control is important during approach run to fly farther. The muscle groups of limbs during approach run maintain posture while regulating the muscle contraction at the high-speed. Therefore, a significant difference might appear in performance between top-level players and amateur players during approach run. We measured EMG signals and knee joint angles to study the difference.

METHODS: Subjects were an amateur (a high school student) and a top-level player (an Olympic player). The ground was a normal-hill. We measured performance in a simulation jumping and a real jumping. EMG signals were measured form vastus lateralis, biceps femoris, tibialis anterior, and gastrocnemius muscle. We also measured the knee joint angles with a flexible goniometer. The intervals for analysis were extracted during take-off at the end of approach run. We analyzed EMG signals by the short-term Fourier transform (STFT) referring to the knee joint angles.

RESULTS: In a simulation jump, muscle activity for maintaining posture during approach run, there was not a remarkable difference between an amateur player and a top-level player.

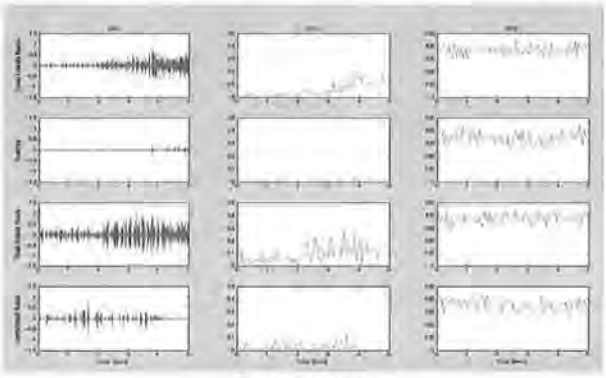

Fig. 1, top-player

However, the remarkable difference occurred at vastus lateralis and tibialis anterior muscles, in a real ski jumping. The difference could be related to the ability for controlling cooperative muscle activity and explosive muscle force while resisting the high-speed and the gravity. That is, the averaged rectified value (ARV) was larger and the mean power frequency (MPF) was 20 Hz higher in the top-level player than that in the amateur player. Before and after take-off, ARV and MPF changed significantly in the amateur player. In addition, there was the silent period before the maximum muscle contraction at the take-off, only for the top-level player. The duration of the silent period was 0.05 ms.

CONCLUSIONS: Neuromuscular system generates the preceding silent period, which is supposed to be a reflection of exhibition in order to effectively control cooperative muscles for the following explosive muscle contraction. We observed the preceding silent period only for the top-level player before the take-off. Moreover, the superiority and inferiority in the control and adjustment affected ski jump performance.

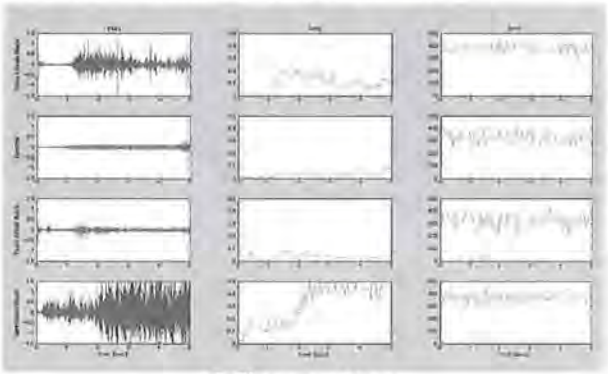

Fig. 2, amateur-player

T02.P17
WAVELET ANALYSIS OF EMG WAVEFORM RELATED TO SPONTANEOUS AND VOLUNTARY BLINKS

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AIMS: The purpose of this study was to evaluate the spontaneous blinks as the involuntary activity of m. orbicularis oculi and the voluntary blinks by means of the application of the Wavelet Transform to the EMG. In our previous study, the both kinds of blinks were evaluated by the amplitude and the duration of the EMG because the EMG relation to the blinks were the non-stationary signals. Wavelet transformation analyses give an optimal time-dependent frequency decomposition of the evoked EMG responses, something difficult to be achieved with previous methods such as the Fourier Transform.

METHODS: Subjects were 12 healthy male students. Their mean age was 20.8 years old with a range of 18-22 years old. They all had a normal vision and did not wear glasses or contact lenses during the experiment. The EMG activity of m. orbicularis oculi was recorded by means of Ag-AgCl surface electrodes with 5mm in diameter using a bipolar lead system. Two electrodes were fixed at 10 mm below the lower eyelid on the left side of m. orbicularis oculi. To begin with, the EMG in association with spontaneous blinks were measured 10 times. Next, the EMG waveform related to the voluntary blinks were measured 10 times each subjects. The EMG signal was continuously stored into a personal computer through an A/D converter with 12-bits resolution and with sampling frequency 1-kHz. Time-frequency analysis of the data was conducted using wavelet-based analysis. The Wavelet Transform is defined as the convolution between the signal $x(t)$ and the wavelet functions $\Psi_{a,b}(t)$

$$W_{\psi}X(a,b) = \left\langle x(t) \mid \psi_{a,b}(t) \right\rangle$$

where $Y_{a,b}(t)$ are dilated and shifted versions of a unique wavelet function $\Psi(t)$

$$\psi_{a,b}(t) = |a|^{\frac{-1}{2}} \psi\left(\frac{t-b}{a}\right)$$

(a, b are the scale and translation parameters, respectively).
RESULTS: Fig. 1 showed the EMG waveform and its spectrogram for the typical voluntary blinks. It was treated the onset of blinks as 0 ms in time scale. The most striking feature of the spectrogram was the increase in energy that occurs from approximately 50 ms with the peak at 42 Hz. After 30 ms of the first peak, the main frequency of EMG was moved to 36 Hz. The power of main frequency decreased. The spontaneous blinks resembled the voluntary blinks in the characteristics of the map of Morlet wavelet transform. Though the main frequency of the spontaneous blinks was lower than that of the voluntary blinks.
CONCLUSIONS: These results add further details as to what difference between the voluntary and involuntary muscle contraction from the view point of time-frequency of the evoked EMG activities.

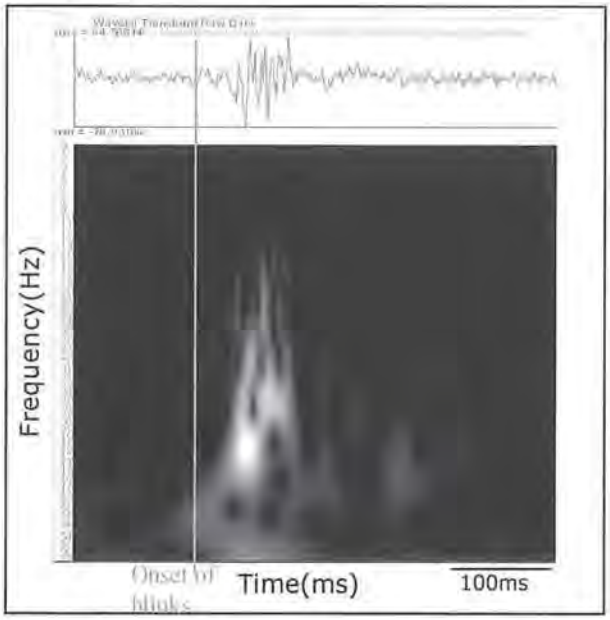

Fig. 1: Gray map of Morlet wavelet transform of EMG signal for voluntary blinks. Dark areas indicate low power values whereas light areas show high power.

T02.P18
A NEW DEVICE TO MEASURE THE ELETROMYOGRAPHIC SIGNALS EASILY

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2) Tokyo Institute of Technology, Yokohama, Japan

AIMS: To get EMG signals, the previous measurement devices had some difficulties; it took time to post the electrodes and another line to take the body grounding was needed. Users feel annoyed in such points. The aim of this paper is to propose the novel device to measure the emg signals easily. To test for the possibility of the proposed device as the useful human interface, we designed the human interface that enables a user to control MIDI player's properties such as volume or speed.
METHODS: We have been developing a new type of human interface using surface EMG signals. This novel divece, whose demension is 45 centimeters by 16 centimeters, has an aluminum body grounding bar, whose length is 13 centimeters and dinameter is 25 millimeters, at the front of it. The bar is separated by 24 centimeters from the electrode whitch is the nearest. Therefore, the EMG can be measured stably by anyone. In order to measure the emg signals, the device has four silver active electrodes on its bottom plate. This active electrode is small, whitch demension is 18 millimeters by 12 millimeters, and has two silver plates. They are separated by 8 millimeters each other. As an application of this novel device we have created a virtual MIDI sound player. The user sat on a chair in front of desk. If the user puts his arm on the device and grasps the bar, the EMG signals are measured when the user stressed on their arm or push the bar to right or left. The EMG signals were rectified and filtered. The maximum and the minimum threshold of the filtered EMG signals are configured. the range of the EMG signals are transformed the range of speed of playing MIDI files. The timing and magnitude of the hand force was calculated from the EMG signals.
RESULTS: In all the channels of the electrodes, the EMG signals were in the same phase. It suggests that we can measure the EMG signals stably at any channels. So we can describe that the EMG signals are measured stably when we use this device. And we used the measured EMG signals to change the playing speed of the MIDI files. The proposed device is familiar to the user. The user can feel that he controls the MIDI player directly by his arm because the intensity of the sound is proportional to the degree of his muscle activity. if the user stresses strongly, the playing speed would become faster. And the playing speed became as we had expected.
CONCLUSIONS: Using this new device, we could get the EMG signals easily. And the user could control the MIDI player. The new device is very simple and convenient to use. there is no need more annoying wire. this portable system could be used at home (for entertainment) or hospitals (for music therapy).

Figure 1: new device for measuring the EMG signals easily, which has four electrodes and a body ground bar

T02.P19
ESTIMATING SQUARE-SHAPED TERRITORY OF SINGLE MOTOR UNITS USING SURFACE ELECTROMYOGRAMS

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AIMS: A surface electromyogram (SEMG) has been utilized to analyse muscle activities and behaviors of single motor units

(MUs) during voluntary motion in the field of neural science, sports science, and clinical medicine. Rectified and smoothed EMGs have also been widely used for measuring muscle activities. Shape and locations of motor units (especially the distance from the skin surface to a motor unit) affect the surface motor unit action potential (SMUAP), however, this has not been actually under consideration in the analysis of SEMGs. The aim of this study is to propose a new method for estimating the territory and location of single motor units using multi-channel SEMG for the precise measurement of the muscle activities.
METHODS: An eight-channel SEMG in human first dorsal interosseous muscle (FDI) was recorded in the isometric contraction of 10% maximal voluntary contraction (MVC) by means of bipolar electrodes. Each electrode was stainless steel pole of 1 mm in diameter, placed on the skin surface. To characterize and visualize features reflecting the territory and location of MUs, we investigated an SMUAP profile in which the peak amplitude of the SMUAP of an eight-channel EMG was plotted against each channel.
RESULTS: Most of SMUAP profiles were flat-topped, while some of them were bell-shaped. Single SMUAP was represented mathmatically as a function of the location and territory with three-pole model. A novel square-shaped territory model, not the circular-shaped territory model, was proposed to explain these profiles. Both territories and locations of single motor units were estimated for two subjects. A new finding was that most of the square-shaped territories expanded 10-15 mm horizontally along the skin surface.
CONCLUSIONS: Both the square-shaped territory model and SMUAP profile were proposed. Its usefullness for estimating locations and the territory of FDI muscle are also shown.

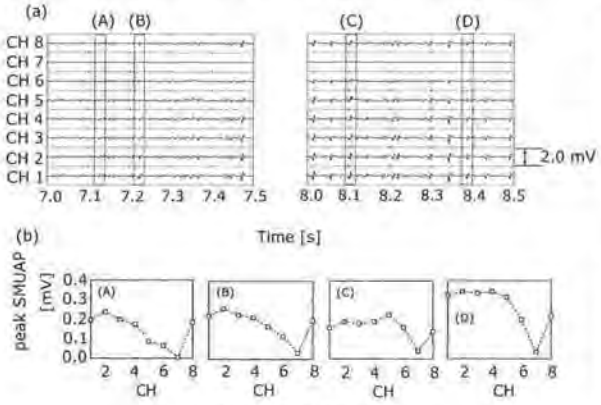

Fig. 1. 10% MVC of FDI muscle.
(a) Eight-channel SEMG. (b) Calculated SMUAP profiles. Figures (A) to (D) correspond to those in (a).

T02.P20
CLINICAL DECISION SUPPORT BY FUZZY LOGIC ANALYSIS OF QUANTITATIVE ELECTROMYOGRAPHIC DATA

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AIMS: A decision support tool is presented that provides an electrophysiological characterization of a muscle based on quantitative EMG (QEMG) data acquired using a concentric needle electrode. QEMG statistics from a single contraction or an entire study (a collection of contractions) are analyzed to produce a characterization describing the disorder type as myopathic, normal or neuropathic with high accuracy and including a probability-based measure of certainty of, or confidence in, the characterization. Such a tool will provide information useful for diagnosis, treatment and management of neuromuscular disorders, increasing the utilization of QEMG data.
METHODS: A hybrid inference system, based on pattern discovery through the use of adjusted residuals and including techniques from "fuzzy inference" was used to analyze training data and produce a rule-set describing relationships between QEMG features and disease states, based on independent analysis of motor unit potential (MUP) characteristics. A confidence measure predicted the probabilistic certainty of an acquired MUP being detected in a muscle affected by a specific disorder. An overall muscle characterization was then produced by combining the data, across the MUPs acquired in a single contraction or an entire study, from each independent MUP analysis, including confidence measures, into an overall assessment. An overall confidence prediction was made and presented along with the characterization obtained from the data for the complete study. Evaluation was performed using data generated by a physiologically-based EMG simulator. Data were produced related to normal, neuropathic and myopathic disease states, with the degree of involvement ranging between 25 and 75%. These data were combined to produce training sets used for QEMG pattern analysis. Testing was performed using contraction data not included in the training data set, using separate tests for neuropathic, normal and myopathic data.
RESULTS: Initial verification shows that compared to considering each MUP individually, combining all MUP data from a study raises the overall probability of providing a correct characterization from 66.8% to 93.9%. Further, initial evaluation of the overall confidence metric indicates that low confidence values are predicted in cases of real error.
Clinically, characterizations of a group of individual MUPs are used. The wisdom of this approach is borne out by the improved success shown. Further performance analysis as real data is added will allow validation of the overall methodology. The ability to successfully detect the presence of only 25% of simulated disease involvement suggests important clinical potential as a screening tool. The system runs on a desktop computer similar to those currently provided for QEMG; as such the analysis can easily be combined with existing decomposition tools.
CONCLUSIONS: Presentation of an interpretive tool with high reliability and exceptional transparency will allow physicians to better understand and hence more often take advantage of QEMG data. Validation of the system with real data and further refinement to characterize the degree, as well as the presence, of involvement will further enhance the utility of the system.

T02.P21
WAVELET ANALYSIS REFLECTS THE INTERPLAY OF HIGH AND LOW EMG FREQUENCY COMPONENTS WHILE RUNNING

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AIMS: Muscles consist of fast and slow conducting muscle fibers either because of their size or because of their fiber type. During a movement one observes on average periods of EMG activity at higher and lower frequencies. The aim was to separate periods with different EMG power spectra in runners and study their relationship and variability.
METHODS: 40 male and 40 female runners ran at 4 m/s with and without shoes while EMGs were recorded from different lower leg muscles. EMGs from the tibialis anterior and the gastrocnemius medialis were submitted to a wavelet transform described in the year 2000. The result are intensity patterns or scalograms that can be averaged. The averaged intensity has to be interpreted as the probability of a muscular event occurring at a certain time and frequency.
The degree of variability and the relationship of muscular events was studied using a principle component (PC) analysis. The input to the PC-analysis was either a number of intensity patterns or a set of time series. In both cases the PC-axis represent the correlated features of the input that are responsible for the variability. The PC-axis are ordered according to their overall contribution to the variability.
RESULTS: Muscular events did occur with different EMG power spectra at different times while running. Typically the tibialis anterior showed a pre- tuning of the muscle with high EMG frequency components before heel strike and a drop to lower

frequencies thereafter. The gastrocnemius medialis muscle, however, showed an onset at lower EMG frequencies and high frequency components gradually contributed more to the EMG power spectra. The PC-analysis of these observations showed that certain muscular events are negatively correlated. For example, if pre-tuning of the tibialis anterior increases, the post heel strike event diminishes while the summed intensities remain fairly constant. Individual running styles differed with respect to using more pre or post heel strike activity. In this case the average does not reflect the behavior of the majority of runners.

CONCLUSIONS: The combination of EMG analysis by wavelets and PC-analysis clearly revealed that muscular events which occur at different times during a movement do not have the same power spectrum and that activities that occur at different times may well be correlated. If muscular events are correlated then the fluctuations reflect an interplay of muscular activity and cannot be attributed to a statistical variability at a single time point. The high variability can be caused by correlated muscular events that are used in different proportions and are individually adapted to perform a stable movement. The reasons for different muscular events having different power spectra must be related to properties of motor units and their activation. The most tempting explanation would be that spectral differences reflect the interplay between groups of motor units containing faster or slower conducting muscle fibers.

Incontinence and pelvic floor

ABDOMINAL AND PELVIC FLOOR MUSCLE ACTIVATION DURING COUGHING IN WOMEN WITH AND WITHOUT URINARY INCONTINENCE

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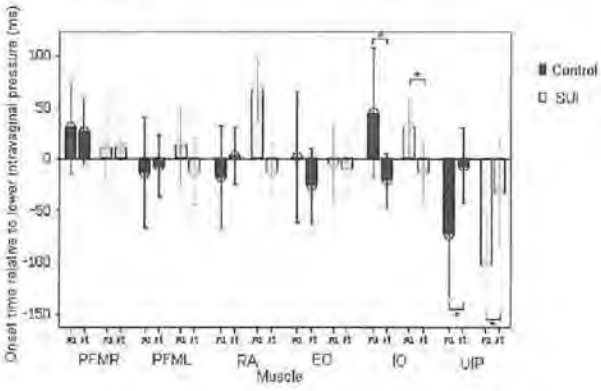
AIMS: The objectives of this study were: (i) to compare the patterns of abdominal and pelvic floor muscle (PFM) activation during coughing between women with and without stress urinary incontinence (SUI) and (ii) to evaluate the effect of position (supine and standing) on abdominal and pelvic floor muscle activation patterns during coughing.
METHODS: Nineteen women with SUI and 19 age- BMI- and parity-matched control subjects participated. Bipolar surface electrode pairs were placed over the left rectus abdominis (RA), external obliques (EO) and internal obliques (IO). A customized intravaginal probe was used to measure PFM activity bilaterally and intravaginal pressure from the upper and lower vaginal canal. In each position (supine and standing), maximum voluntary contractions (MVC) of each of the abdominal and PFM were performed. This was followed by the performance of three maximal voluntary coughing efforts. Cough force was monitored using a peak flow meter. The timing of muscle activation relative to the onset of intravaginal pressure was computed for each cough and was compared within each group using a twoway repeated-measures ANOVA including the main effects of muscle and position and the interaction between the two. Maximum activation amplitudes were computed for each MVC and were compared between groups and positions using a two-way ANOVA. Since there were significant group and position effects for the maximal abdominal EMG and the maximal intravaginal pressures, the coughing data were not normalized to maximum values. Instead, two-way ANOVAs were used to test the effect of group and position on the raw EMG and intravaginal pressure data. An α-level of 0.05 was used for all tests.
RESULTS: The key onset time results are presented in Figure. There were no group by position interactions and no group main effects found for any muscles tested. A significant position effect was found for IO, which was activated after the initiation of lower intravaginal pressure in supine but before the rise in intravaginal pressure in standing, and for upper intravaginal pressure which was activated earlier in supine than in standing. For activation amplitudes, a group main effect was found for all the muscles and pressures, whereby the incontinent group generated lower activation amplitudes during coughing in both positions when compared to continent women. Similarly, during coughing the SUI group produced a lower flow rate in both positions when compared to the continent women ($p<0.0005$).
CONCLUSIONS: Abdominal muscle activation times do not differ between continent and incontinent women. Muscle activation amplitude and intravaginal pressure during coughing are lower in women with SUI.



95% ci for abdominal and PFM onset times during cough in supine (SU) and standing (ST)

DETECTION OF NEUROGENIC DETRUSOR OVERACTIVITY BY ANALYSIS OF URETHRAL SPHINCTER EMG

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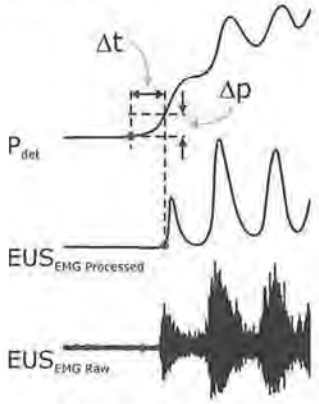
AIMS: The objective of this study was to investigate the feasibility of using external urethral sphincter (EUS) EMG to detect the onset of involuntary detrusor contractions in patients with both neurogenic detrusor overactivity (NDO) and detrusor sphincter dyssynergia (DSD). The long-term research goal is the development of an implantable neuroprosthesis that utilizes closed-loop conditional stimulation in order to treat NDO.
METHODS: A urodynamic study using slow artificial bladder filling (≤20 ml/min) was performed on 23 neurogenic patients (13 males, 10 females). Vesical pressure and abdominal pressure were measured using an 8Fr double lumen water filled catheter and a 9Fr water filled rectal balloon catheter, respectively. Two fine wire electrodes were inserted into the periurethral musculature for EMG recording of the EUS. The time delay (Δt) between the onset of a detrusor contraction and the onset of EUS EMG activity was calculated together with the detrusor pressure increase (Δp) related to this delay (see Figure). A method was subsequently developed for determining an optimal bin-size for bin-integration together with a bin-integration algorithm that maintains the energy in pressure-related EUS EMG signals and downscale nonpressure-related activity in order to avoid false-positive detections.
RESULTS: Of 23 patients enrolled, 12 patients showed both NDO and DSD. Of these 12 patients, 10 had a strong correlation between detrusor pressure (P_{det}) and EUS EMG. In 9 out of these 10 patients, onset of EUS EMG activity occurred before Pdet exceeded 10 cmH_2O. In this group, the average time between the onset of a detrusor contraction and the onset of raw EUS EMG activity was 2.4 ± 2.8 s with a corresponding average P_{det} increase of 1.8 ± 1.9 cmH_2O (determined by visual inspection). With the developed algorithm, the onset of a detrusor contraction could be detected based on the onset of the scaled bin-integrated EMG signal after 3.7 ± 3.0 s with a corresponding average P_{det} increase of 4.3 ± 4.5 cmH_2O.
CONCLUSIONS: Detection of NDO based on analysis of EMG activity needs to be robust as well as automatic. Pressure activated electrical stimulation of pudendal nerve afferents with a threshold of 10 cmH2O has previously been shown to inhibit bladder contractions sufficiently early to prevent leakage as well as to maintain a safe storage pressure. In 9 out of 10 patients with strong correlation between NDO and DSD, the EMG onset could be detected before the detrusor pressure exceeded 10 cmH_2O. The detection was thus sufficiently early in time to suppress NDO before the detrusor pressure becomes too high. This study demonstrates the feasibility of using sphincter EMG to estimate the onset of a detrusor contraction in selected patients.



Calculation of Δt and ΔP

A BIOMECHANICAL MODEL OF INTRAVAGINAL PRESSURE GENERATION COMPARING CONTINENT AND STRESS INCONTINENT WOMEN

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AIMS: We have previously modeled the relationship between abdominal (AB) and pelvic floor muscle (PFM) activity and intravaginal pressure in a sample of urinary continent women. In this study we used the same method to compare women with stress urinary incontinence (SUI) to age-matched continent women.

METHODS: PFM electromyography (EMG) data were acquired using a FemiscanTM probe seated in the vagina. The probe had two lateral pairs of bipolar electrodes and was modified by mounting a pressure transducer in a hole cut through its posterior surface. Surface EMG data were recorded from rectus abdominis (RA), internal obliques (IO) and external obliques (EO) using Ag-AgCl adhesive electrodes. EMG data were amplified (Bortec AMT-8), and EMG and pressure data were acquired at 1kHz using a 16-bit Analog to Digital Converter and Labview™ v. 6.1 software. All data were stored on a personal computer.
After a period of instruction to familiarize subjects with the proper performance of a PFM contraction, volunteers performed three repetitions of a maximum voluntary contraction of their PFM while EMG and pressure data were recorded simultaneously. All pressure and EMG data were smoothed by computing root mean square (RMS) values using a 20ms moving window across the contraction time after removing the baseline RMS value from each data set. The data were normalized based on the maximum smoothed pressure or EMG amplitude achieved during each contraction. The normalized pressure vs. EMG curves were then ensemble averaged, and the best equations (determined using F-tests between curves) were computed for each muscle. The pressure vs. EMG curves were compared between the control and SUI groups using student t tests (α=0.05).

RESULTS: Twenty-nine urinary continent women and thirty women with SUI (age 46.6±7.8, and 46.1±7.2, respectively, p= 0.8) participated in the study. In the continent women, the ensemble average pressure vs. EMG curve for the PFM was best modeled by a second order polynomial equation (R^2_{PFM}= 43.9%), while for the three AB muscles the pressure vs. EMG relationships were best modeled as straight lines (R^2_{RA}= 61.2%, R^2_{EO} =40.9% and R^2_{IO} =46.8%). All coefficients within the equations were significant (p<0.001). In the women with SUI, the EMG vs. pressure relationships for the PFM and the AB muscles were all best modeled as straight lines (R^2_{PFM}= 46.0% R^2_{RA} =48.5%, R^2_{EO} =43.7% and R^2_{IO} =52.3%) and all were significant (p< 0.001). To compare the groups, the slopes and intercepts of the straight lines were used for all muscles except the PFM. None of the intercepts, indicating percent EMG activation level at the onset of the rise in intravaginal pressure, were significantly different between the groups (p>0.05). Only RA demonstrated a significant difference in slope between the groups (p<0.05) the rate of increase in EMG activation relative to the increase in pressure was higher in the group with SUI. When the PFM activation vs. pressure was modeled using a straight line (R^2_{PFM}=43.88%), there was no difference in slope or intercept between the groups.

CONCLUSIONS: The similar intercepts for all muscle groups suggest that AB and PFM activation levels at the onset of the vaginal pressure were not different between the groups. The difference in slope seen in RA may indicate that (i) subjects use RA, or an increase in abdominal pressure, to compensate for weakness in the PFM, or that (ii) the rapid rise in RA activation is a contributing factor in SUI. The difference in PFM curves between the control group and the women with SUI may or may not be clinically significant. The findings in this study suggest that motor control deficits in women with SUI are not likely related to alterations in PFM or abdominal muscle activation as it relates to pressure generation.

POSTURAL RESPONSE OF THE PELVIC FLOOR AND ABDOMINAL MUSCLES IN WOMEN WITH AND WITHOUT INCONTENCE

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AIMS: Pelvic floor muscles (PF) contribute to lumbopelvic stability via their attachments to the pelvis and their contribution to intra-abdominal pressure. This study aimed to determine whether activity of the PF and abdominal muscles differs between continent and incontinent women in response to a postural perturbation.

METHODS: Sixteen women with stress urinary incontinence and fourteen women with no history of incontinence participated in the study. Electromyographic (EMG) activity of the PF, abdominal, errector spinae (ES) and biceps brachii muscles was recorded with surface electrodes prior to and after a postural perturbation in which a 1 kg weight was dropped 30 cm into a bucket held by the subject. The timing of the release of the weight was unknown. Due to the inability to normalise EMG to maximum voluntary contractions in this population, and as no systematic differences were expected in subcutaneous tissue, data were analysed as raw EMG amplitude.

RESULTS: EMG activity of all muscles increased in response to the addition of load to the trunk. Women with incontinence demonstrated increased PF EMG compared to continent women both prior to and during the postural response associated with loading. In addition, obliquus externus (OE) EMG was increased in incontinent women. When incontinent women were divided into two groups based on reported severity of symptoms, women with more severe incontinence had a trend for greater PF EMG activity than continent women, but significantly greater OE EMG than either women with mild incontinence or controls. Conversely, women with mild incontinence had greater PF EMG than continent women, but no difference in OE EMG.

CONCLUSIONS: These data suggest that women with incontinence have increased PF and OE muscle activity associated with postural perturbations. This finding challenges the clinical assumption that incontinence is associated with reduced PF muscle activity. However, it is unclear how greater EMG activity during these tasks is related to strength and endurance which have been shown to be impaired in people with incontinence. The increased activity of the OE muscle is likely to increase the deamnd on the pelvic floor muscles. Although comparison of raw EMG is problematic, any reduction in mass of the PF muscles (as has been reported previously) would be expected to lead to reduced EMG amplitude, rather than an increase as found here. The data has several implications for rehabilitation. Although PF muscle strengthening may be an effecitve rehabilitation startegy for stress incontinence, if increased OE activity is present, as demonstrated in women with more severe incontinence, attempts to decrease abdominal muscle activity, or retrain coordination of the abdominal and PF muscle groups, may contriubute to symptom reduction. Finally, altered PF and OE muscle activity in women with incontinence may affect stability of the lumbopelvic area. This may relate to the higher prevalence of back pain in women with incontinence that has been reported in cross-sectional and longitudinal studies.

T03.P01
NON-INVASIVE ASSESSMENT OF THE GRACILIS MUSCLE BY MEANS OF SURFACE EMG ELECTRODE ARRAYS

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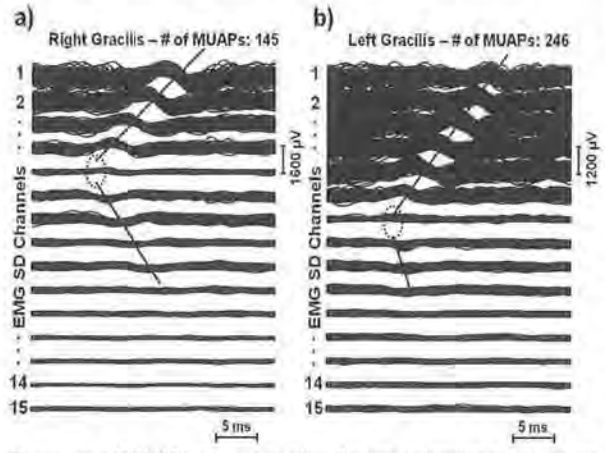
AIMS: The purpose of the study was the non invasive investigation of the innervation zone (IZ) location of the gracilis muscle of both thighs by means of surface electromyography (EMG).
METHODS: Multichannel EMG signals were detected by means of a flexible array of 16 equally spaced silver bar electrodes. Tests were performed on both gracilis muscles on 15 subjects. The subjects were laying supine on a bed with the legs opened at an angle of 15° with respect to the medial sagittal plane (30° between the legs), and were asked to contract the gracilis against a resistance placed between the knees. The anatomical landmark often considered as the upper limit of the lower extremity is the inguinal fold. It is also the place where manual localisation of the gracilis muscle seems to be fairly easy due to relatively thin subcutaneous tissue layer. This is why manual location of the muscle was made at this level. Then a line was drawn between the medial epicondilis of the tibia and the palpated edge of the gracilis to help electrode placement. Only the most proximal muscle portion (16 cm) was investigated. The electrode array was placed parallel to this line, with the first electrode most proximal to the origin of the muscle. Motor unit action potentials (MUAPs) were visually identified and extracted (see figure). The locations of the innervation zones of the recognized MUs were statistically analyzed in order to find significant differences between the subjects and between the right and left muscle of each subject.
RESULTS: A statistically significant difference was found between the gracilis IZ position in the two sides, with more proximal IZs on the left side (about 1 cm difference). This difference suggests a possible role of sEMG in preoperative evaluation of patients prepared for the dynamic graciloplasty procedure. This test would provide an objective criterion for the choice of the gracilis muscle to be transposed with the highest probability of success.



Examples of MUAPs extracted, classified as belonging to the same MU and superimposed from two signals acquired from the gracilis muscles of a representative subject. The innervation zones are indicated by a dotted ellipse. a) Right side, b) Left side. The number of superimposed MUAPs is shown for both panels. Electrode 1 was the most proximal, as it was placed at a distance of 0.5 cm from the inguinal fold.

CONCLUSIONS: The main objective of this study was not to provide indications about the optimal choice of the muscle to transpose because sample size is not representative for that purpose, but rather to demonstrate asymmetry between the IZ locations of the right and left gracilis muscles and thus justify preoperative evaluation of innervation zones. This suggests the application of the technique described in this work before dynamic graciloplasty in order to evaluate on each specific subject the IZ positions and thus to plan the operation depending on an objective criterion.
Surface EMG is able to detect the location of the innervation zones of gracilis muscle. We observe high variability in position of IZs both between subjects and between the legs of the same subject. We suggest that sEMG performed preoperatively would give information helpful in planning gracilis muscle transposition. Direct impact of this method on final outcome of dynamic graciloplasty remains to be investigated.

T03.P02
APPLICATION OF THE ELECTROMYOGRAPHIC BIOFEEDBACK IN THE INCONTINENCE ANAL AND PELVIC FLOOR

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Unigran - Centro Universitário da Grande Dourados MS

AIMS: The biofeedback electromyographic is considered an effective treatment for anal incontinence, but a substantial proportion of patients fails to improve. The purpose of this study was to verify the efficiency of the application of EMG in the study of the anal incontinence as well as to verify the fidelity as quantification instrument during the treatment
METHODS: The EMG activity was captured by an *EMG System do Brasil Ltda* composed of bipolar anal electrode filters with band of frequency 20 to 1000 Hz, way CMRR of 120 dB, converter A/D of 14 bits and sampling frequency 2000 Hz. In all of the procedures of the sign EMG, were following the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK) relative to the job of the electromyographic. The treatment of the sign was constituted in rectification by wave completes, lineal wrapper through filter Butterworth of 4th order, cut frequency of of 5 Hz, normalized in the base of time and of the intensity, and the intensity was normalized by the average. The variability of the intensity of the sign EMG was calculated through the variability coefficient (CV). The comparison among the signs of EMG of the different studied patients was made through the test-t for parallel samples, and the level of adopted significance was of 0,05. We retrospectively analyzed the clinical and physiologic data of 20 patients consecutively treated in our unit for anal incontinence by electromyographics biofeedback. Clinical evaluation was performed by means of a structured questionnaire that included previous history, symptoms of incontinence, and bowel habit. Anorectal evaluation measured anal pressure profiles and registration of the EMG signs, defecatory dynamics, rectal compliance, and rectal sensitivity. Biofeedback treatment was performed by a manometric technique with reinforcement sessions scheduled every three months and daily exercising at home.
RESULT: Of 20 patients (20 female; age range, 50±10 years) with at least three-month follow-up, 84 percent had a good response to treatment. By univariate analysis, several factors, such as age, history of constipation, abnormal defecatory maneuver, and rectal compliance, were significantly related to treatment response, but by multivariate logistic regression only age and defecatory maneuver were independent predictors of the response. The association of both factors provided the best sensitivity and specificity; 48 percent of patients younger than age 55 years and with abnormal defecatory maneuver had negative response to treatment, whereas 96 percent of patients age 55 years or older with normal defecatory maneuver had a positive response.
CONCLUSION: In patients with anal incontinence scheduled for electromyographics biofeedback treatment, potential alterations of defecation should be first searched for and corrected, particularly in younger patients. Biofeedback training improves

continence in patients not only during treatment and within the first two years but also for several years after therapy. The employment of biofeedback training to obtain improvement of the threshold of rectal sensibility (minimal volume of endoluminal distention to produce the sensation of imminent defecation and external anal sphincter contraction) has proved useful in the rehabilitation of incontinent patients.

T03.P03
INTRAOPERATIVE CONFIRMATION OF SURFACE EMG NERVE BUNDLE ENTRY POINT LOCALIZATION OF GRACILIS MUSCLE IN HUMANS

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INTRODUCTION: Literature review and previous experience of authors suggest that surface electromiography (sEMG) is a good tool to localize innervation zone (IZ) of skeletal muscles. No data is available on degree of correspondence between IZ and surgically important nerve bundle entry point to the body of the muscle.
AIMS: We would like to verify surgically precision of gracilis muscle IZ localization with use of sEMG. We also wanted to assess if sEMG findings correspond to surgically estimated nerve bundle entry point.
MATERIAL and METHODS: Preoperative localization of IZ was performed in 7 patients on 8 occasions. Linear array of 16 silver bar electrodes spaced 1 cm one from another was used with sEMG amplifier and PC based recording software. At least 3 voluntary contraction recordings were performed to localize IZ. If necessary additional recordings with more precise array with tip electrodes spaced 2 mm apart was used. Localization was marked with skin marker. During surgical procedure involving mobilization of gracilis muscle and visualization of its proximal nerve bundle distance from skin mark to nerve bundle entry to the body of the muscle was measured. In 2 cases there was a need to expose previously implanted electrodes placed near nerve entry point on transpositioned gracilis muscle. We used the same way of localisation but for obvious reasons stimulated contractions were recorded.
RESULTS: In all cases we were able to localize IZ. In 6 cases non stimulated contractions enabled precise localization of IZ. Distance from skin mark to nerve entry point was between 5 and 10 mm (mean 6,4). In 2 cases of localization of previously implanted electrodes IZ detection was even more precise and distance was below 5 mm.
CONCLUSIONS: Surface EMG is a valid and precise method of IZ localization. Moreover, IZ corresponds well to anatomical findings, surgically more important then electrophysiological ones thus making sEMG a valuable tool for Innervation Zone localization.

Gait and movement analysis

EFFECT OF ELECTRODE LOCATION ON EMG SIGNAL ENVELOPE IN LEG MUSCLES DURING GAIT

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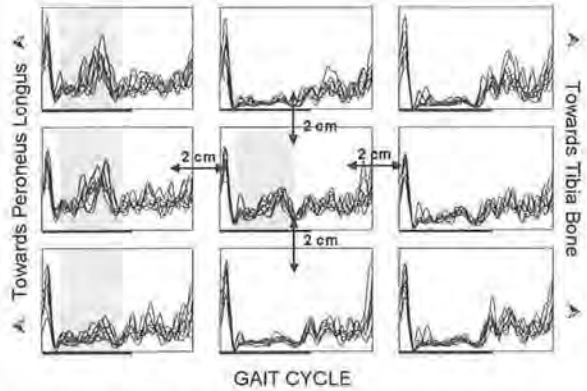
AIMS: The aim of the study was to assess the variability of EMG signal envelope with electrode location in the leg during gait.
METHODS: Surface EMG signals were recorded from 10 healthy subjects (5 females; age, 29±9 yr) from the tibialis anterior (TA), peroneus longus (PL), gastrocnemius medialis (GM), gastrocnemius lateralis (GL), and soleus (SO) muscles using a grid of 4x3 electrodes (15x20 mm) with interelectrode distance 20 mm in both directions. For SO, a 3x3 electrode grid was used. Envelope was characterized by its peak value, area after normalization by the peak value, and time instant corresponding to the maximum. The variation of envelope descriptors with electrode location was computed and expressed as a percentage of the value in the central location. A crosstalk index (CTI) was also defined as the ratio between the area of the normalized envelope outside the expected activation phase of the muscle and the area of the entire normalized envelope.
RESULTS: The maximum variation of peak value with electrode location, expressed as a percentage of the peak in the central location, was (mean±SD) 31±18% for TA, 29±13% for PL, 25±15% for GL, 14±8% for GM, and 26±14% for SO. The maximum variation in area was 29±13% for TA, 73±40% for PL, 31±23% for GL, 35±20% for GM, 20±13% for SO, and in the position of maximum, computed as distance from the maximum position in the central channel, it was 5±10% of the gait cycle for TA, 26±16% for PL, 3±2% for GL, 3±1% for GM, 3±3% for SO. For TA, CTI progressively increased from the medial column of the grid to the lateral column, which was close or partially over PL (an example is provided in the Figure). Accordingly, for PL, CTI increased from the lateral to the medial column of the grid. CTI was approximately uniform with electrode location in GM, GL and SO.
CONCLUSIONS: The intensity of muscle activation, quantified by the peak value and area of the envelope, showed large variability among channels (in the worst case) for all muscles while the position of the maximum point of the envelope was stable for GL, GM, and SO and more variable for TA and PL, probably due to crosstalk. It is concluded that the determination of muscle activation intensity during the stride from surface EMG may be critical while timing of muscle activity can be reliably assessed when crosstalk is limited.

This work was supported by a grant of Fondazione Pietro Manodori, Italy.



Envelope (all strides of a subject) from TA in the nine locations. Grey stripes outline the presence of activity in mid and terminal stance, due to signal coming (probably) from PL. Vertical scale: 0 - 100 μV

CONTROL OF HEAD STABILITY DURING GAIT INITIATION IN YOUNG AND OLDER WOMEN

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AIMS: Transition tasks, such as gait initiation, involve complex interactions between neural and biomechanical factors that challenge postural stability and may lead to falls in older individuals. Alterations of lower limbs muscular activity aimed to initiate locomotion have been documented to occur with ageing. Previous investigations have revealed that head stabilisation plays an important role for the maintenance of whole body balance during locomotion, since it establishes an inertial guide platform and optimises visual and vestibular functions, but there are no data on gait initiation. The present study, therefore, aimed to compare control strategies employed by healthy young and older people for the maintenance of head stability during gait initiation.
METHODS: With ethics committee approval, 7 healthy young women (25±2.3) and 7 healthy older women (78±3.4) volunteered for the study. Both groups performed 10 trials, each of which consisted of taking two-three steps forward at their most comfortable speed starting with the right leg from a standing position and focusing on a target placed 2 m away. A six camera VICON 612® system was used to acquire trajectories of markers placed on the upper body landmarks (apex of the skull, occipital bone, C7 and L5 vertebrae). Sagittal-plane angular displacements of the head, neck and trunk segments were then calculated with respect to an external horizontal reference. A force plate (AMTI OR6-6) was used to calculate the displacement of the centre of pressure (COP). All data were selected from -500 ms to +500 ms with respect to the onset of the COP motion. Principal Component Analysis (PCA) was used to extract basic functions that were descriptive of the two groups data set of head angular displacements in the sagittal plane.
RESULTS: During the preparatory phase of gait initiation, head stabilisation was maintained in both young and elderly individuals throughout the head-neck extension, which anticipated and counteracted the trunk flexion. In the young participants the first principal component consisted of a smooth extension of the head and explained 72% of the total variance. In contrast, in the older participants the first principal component involved slight extension-flexion wavering that preceded the head extension and explained 57% of the total variance. As a consequence, the time of occurrence of head extension relative to COP onset differed between the two groups of participants, occurring significantly later in the elderly with respect to the young (134.85±88.24 ms vs 15.5±102.43 ms; $p < 0.05$).
CONCLUSIONS: In both young and older women the head is extended to counteract the forward flexion of the trunk at the onset of gait initiation. However, the head extension is perturbed and delayed in the older women, thus suggesting an altered strategy in the control of head stabilisation, which might ultimately lead to a reduced balance.

MUSCLE ACTIVATION PATTERNS DURING GAIT IN CHILDREN

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AIMS: The knowledge of the characteristics of normal gait, of its variability, and of changes that take place with age are of paramount importance to understand gait disorders in childhood and adolescence. Although an extensive body of knowledge is available regarding children between 1 and 7 years of age, data relative to subjects aged between 7 and 12 are scarce. Moreover, data regarding muscle activation published in the past may suffer from poor awareness of the crosstalk phenomenon, which may

be particularly important in small sized limbs, like those of children. The aim of this work is to describe the most common muscle activation patterns found in normal children aged between 6 and 12, and it is part of a more ambitious project aimed at describing a more complete set of gait parameters on a large population.

METHODS: For this study, we enrolled 54 children (32 females and 22 males) aged between 6 and 12 years, with no apparent gait abnormalities or history of neuromuscular or orthopaedic disorders. Each subject underwent a statistical gait analysis session carried out with a commercial system (STEP 32, DemItalia srl, Leini, Italy). Sensors allowed for describing foot-contact (3 switches, 4 levels), knee joint goniometry, and EMG signals obtained from Tibialis Anterior (TA), Lateral Gastrocnemius (GSC), Rectus Femoris (RF), Vastus Medialis (VM), and Biceps Femoris (BF) muscles. EMG signals were collected by means of fixed geometry probes with 12mm of interelectrode distance, whose spatial selectivity allows for considering as negligible crosstalk between adjacent muscles in our subjects. Each subject walked back and forth over a distance of 12m for at least 2 minutes. Gait parameters were obtained through the software provided by the system, which is completely user independent.

RESULTS: The table below shows the distribution of the number of muscle activations per each gait cycle for the studied muscles. The analysis was restricted to straight walk only. No significant difference was found between males and females or between left- and right-side muscles. It was also demonstrated that the distribution of the number of muscle activations did not depend on age. The average percent amount of plantar flexor and extensor coactivation around the heel strike is currently under investigation. Moreover, we found that the 3-activation modality of the TA muscle is due to two different strategies, one of which not yet fully understood. Complete results and their thorough discussion will be proposed in the presentation.

CONCLUSIONS: This work describes gait parameters in a population of 54 children. To our knowledge, the age interval of our population has never been considered in a large study before. We believe that our results constitute a normative data base, which can be very helpful for understanding gait abnormalities in childhood and adolescence.

acts	1	2	3	4	5	total steps
TA	1%	24%	49%	21%	5%	4391
GSC	32%	33%	25%	8%	2%	4058
RF	2%	30%	50%	15%	3%	3620
BF	2%	48%	36%	12%	2%	4009
VM	1%	61%	28%	7%	3%	4783

JOINT FUNCTION CHANGES IN HEMIPARETIC GAIT AFTER VISUAL EMG BIOFEEDBACK TRAINING

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AIMS: Post-stroke patients often show gait abnormalities related to inappropriate dynamic voluntary activation of the ankle plantar/dorsi-flexors [1]. Retraining of these muscles and related ankle function should be incorporated into a gait-retraining program. The use of dynamic EMG biofeedback procedures to overcome limitations of retraining muscles in isolation has been proposed [2]. Results demonstrated improvements in specific quantitative gait parameters. However, the experimental setup, including overground walking, limited its scope of clinical application. Treadmill walking is often used as a substitute to overground walking and it is especially convenient when used by less functional patients. We hypothesized that treadmill gait retraining with visual EMG biofeedback could be beneficial to hemi-paretic subjects.

METHODS: Eight adults (7M, 1F; age range: 47-59) more than 2 years post-stroke with residual ankle plantar-dorsiflexion strength (MRC≥3), limited spasticity (Ashworth <2), not receiving physical therapy, able to walk at a speed between 0.5 and 0.9 m/s participated in the study. During the training sessions, subjects walked on a treadmill at a comfortable speed and EMG from the gastrocnemius lateralis and tibialis anterior muscles in addition to footswitch signals were collected (five trials of 4 min each). The target EMG (normal activation intervals) and the real-time rectified EMG patterns were shown on a screen display positioned in front of the subject. Before and after the 12-session treadmill training, gait data were recorded (Vicon512). Statistical analysis of the gait data was performed on a subject-by-subject basis. Gait and joint parameters before and after treatment were compared using a two-tailed Mann-Whitney U test (significance $p<.05$, trend $.05<p<.1$).

RESULTS: The p-values for the pre- and post-training comparison of selected gait and joint parameters are shown in Table. Walking speed increased significantly in 5 subjects, decreased in 1, and showed a decrease trend in 1 subject. Affected side single support increased in 5 subjects and showed an increase trend in 2 other subjects. Significant increase in stride length was shown by 4 subjects and 1 subject showed an increase trend. All but 1 subject showed an increase in ankle power generation at push off (significantly in 5 subjects). Changes in knee extensor moment were found in 5 subjects.

n	walking speed	affected side single support	affected side stride length	max plantar. stance	max plantar. push-off	peak ankle power	max flex. mom., stance	max ext. mom., stance
1	**0.016**	NS	NS	NS	**0.032**↓	NS	NS	NS
2	**0.008**↓	**0.008**	NS	**0.008**↓	0.095	NS	NS	**0.008**
3	NS	0.056	0.095	**0.008**	0.056	NS	0.095	**0.008**
4	**0.008**	**0.008**	**0.008**	0.056	0.056	**0.008**	NS	**0.008**
5	0.056↓	**0.008**	NS	**0.008**	NS	**0.008**	**0.008**	**0.008**
6	**0.008**	0.056	**0.008**	**0.008**	0.095	**0.008**	0.095	NS
7	**0.008**	**0.032**	**0.008**	NS	**0.008**	**0.016**	NS	**0.008**
8	**0.008**	**0.032**	**0.008**	0.095	**0.008**	**0.008**	**0.008**	0.095

P-values for changes in selected gait parameters for each of the 8 subjects. Statistically significant (bold) and trend (plain) changes

CONCLUSIONS: An overall positive response to the intervention can be inferred by the significant changes seen in most subjects. By training the gastrocnemious lateralis, subjects achieved timing and magnitude of muscle activity that led to an increase in ankle power at push off. The training of the tibilias anterior enabled subjects to dorsiflex the ankle during swing and attain heelstrike at ground contact aiding foot clearance and reducing circumduction.

[1] Kerrigan et al, J Head Trauma Rehabil, 1999. 14:136-45.
[2] Colborne et al, Arch Phys Med Rehabil, 1993. 74:1100-6.

HUMAN SILHOUETTE TRACKING BY A NEURAL APPROACH: NEURAL SNAKES

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AIMS: The high deformability of human silhouette during movement and the consequent unacceptability to associate a rigid body approximation with it are critical problems in markerless motion analysis. Active Contour Models are widely used in literature [1] for segmentation and contour detection but they are restricted to performing silhouette tracking of objects whose shape subtly changes during movement. For this reason they are not successfully applicable for human tracking during

gait. This paper presents a novel 2D markerless motion capture system for robust extraction of articulated silhouettes by a neural approach. We extend the classical active contour model formulation, known as Snakes [1], by using a Neural Network as a predictor for increasing the capability of this method in case of high deformable shapes. The proposed approach, called Neural Snakes, is evaluated on several video sequences, demonstrating fast and accurate human silhouette tracking.

METHODS: This paper presents a new type of deformable model for contour tracing: the method is based on a closed Active Contour Models (ACM) driven by an Artificial Neural Network (ANN) used as a shape predictor and is called Neural Snakes (NS). The proposed neural approach is based on a multilayer Perceptron (2 hidden layers with 15 neurons each) trained for ACM configuration prediction. Kinematic parameters (horizontal and vertical position, velocity and acceleration of each contour point) in the current frame are the ANN inputs, while the output is the position of each contour point in the following frame. The training set is composed of kinematic parameters of each contour point obtained applying the ACM to several synthetic video sequences with high frame rate (low gradient in shape deformation). After training completion, the ANN is used, frame by frame, to pre-locate the Snake near the silhouette before the application of the classical ACM.

RESULTS: The NS have been successfully applied in tracking selected body parts on walking humans. Preliminary results have been obtained by testing the proposed method on synthetic video sequences where a walking human silhouette moves with mean velocity of 10 pels/frame. The root-mean-square error (RMSE) obtained with the classical ACM is 18,50 pels while the NS presents a RMSE of 1.02 pels. Figure shows a comparative result of the application of ACM and NS to the knee joint area in real human walking video sequences.

CONCLUSIONS: In this contribution a novel method, called Neural Snakes, for a markerless 2D silhouette analysis of human movement is proposed. Results, obtained applying it to numerous experimental tests on real human silhouette video sequences, will show the high level of accuracy attainable.

Comparative result between classical ACM (left) and NS (right)

[1] Kass M., Witkin A., Terzopoulos D., "Snakes: Active contour models", In Proc. 1st Int. Conf. on Computer Vision, 259-268, 1987.

ROBOT BASED METHOD FOR FUNCTIONAL TESTING OF UPPER EXTREMITY MOVEMENT PERFORMANCE

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AIMS: Today is the standardised measurement of the 3-dimensional kinematic data together with surface EMG data the usual procedure in clinical gait analysis. On the other hand, there is a lack of methods for assesment of arbitrary upper extremity movement which is not restricted, repeatable or cyclic as compared to movement during gait. Additionally, in contrast to gait, external forces, which are compensated by the neuromuscular system, are less defined and with lower magnitudes. As a consequence, the interpretation of the muscular coordination pattern detected by surface electrodes becomes complex and sometimes impossible. For that reason, there is a need for a methodology that allows a reliable analysis of movement performance, as well as of the underlying muscular coordination pattern of freely definable 3D upper extremity movements.

METHODS: A robot-arm was used to present a predefined 3D robot path, which should be followed by the subject. Joint angles for elbow, shoulder and sternoclavicular joint were calculated using the kinematic data acquired by a Vicon370 Motion Analysis system and a rigid body model. Muscle activity was tracked by using motion-synchronised bipolar surface EMG according to the SENIAM recommendations. A 6-DOF force sensor attached to the robot-arm and a feedback program were used to help in maintaining the desired force vectors. In this way, muscular activation can be controlled and different contraction levels of muscles can be achieved during free upper extremity movements.

RESULTS: For the movements performed by following the predefined paths (e.g. shoulder flexion) the joint angles for all three joints were calculated. The mean value and standard deviation of five trials performed by a same subject are showing good reproducibility of the movement with a mean cross-correlation factor 0.975. For each predefined movement a typical muscular coordination pattern of the muscles: brachioradialis, biceps, triceps, deltoid and trapezius, could be defined which was in accordance with the movements in the different joints and the generated forces.

CONCLUSIONS: Utilizing this procedure, the reproducible and cyclic upper extremity movement is achieved. A measurement set-up was created, which allows the functional testing of upper extremity movement performance including the execution of the movement as well as the underlying muscular coordination pattern at different levels of contraction. Standardizing the movement, the posibility of comparing data for treatment decision or rehabilitation evaluation is given.

FUNCTIONAL AND BIOMECHANICAL ASSESSMENT IN BIOLOGICAL RECONSTRUCTION OF FEMUR IN CHILDREN WITH BONE SARCOMA

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AIMS: The aim of this study is to quantitatively assess the functional recover of ten yuong patients after biological reconstruction of femur at a long-time follow-up with gait analysis and with adeguate scoring evaluation systems. This unique series represents the largest clinical experience of such techology available wordwilde and this analysis may furnish data to develop more efficient reconstruction and to plan specific post-operative rehabilitation menagment.

METHODS: We evaluated 10 young patients (mean age 12.5 years, range 4-18) affected by bone sarcoma and treated with an original biological reconstruction of femur at a mean follow-up of 6 years (range 1.5-13). Femur resections were proximal in four subjects and distal in six. The innovative surgical technique consisted in replacing the affected skeletal segment by a massive deep-frozen bone allograft suitably prepared to receive on its endostal surface a vascularized fibula autograft. We used an integrated gait analysis system: a VICON (Oxford, UK) stereophotogrammetric system with 8 cameras to calculated rotation angles at the lower limbs joints, two force platforms (Kistler) to collect ground reaction force and a surface electromyograph (telemg) to assess muscle activation. We evaluated both limbs quadriceps with the isokinetic dynamometry: eccentric knee extension peak torque was determined at different range of motion (90°, 60°, 30°, 0°). Two different functional scales were adopted in each patient: MusculoSkeletal Tumor Society (MSTS) Functional Evaluation System, European Organization for Research and Treatment of Cancer (EORTC) Quality-of-Life Questionnaire.

RESULTS: Concerning time-distance parameters we found a light reduction of gait speed in all patients and a short decrease of stride length in the group of subjects with distal resection. In almost all patients there is a reduction of knee adduction moment

and in three patients with distal resection there is a knee extension pattern during loading response with a decreased knee flexion moment. A backward tilt of pelvis is evident in all patients during the entire gait cycle. Pelvis is in a forward position at the side of the operated leg. In the electromographyc pattern of muscles we noticed two alteration: prolungated activation of tibialis anterior during mid and terminal stance in proximal femur resection patients, a shorter activation of maximum and medium gluteus muscles during stance. Mean scores in functional scales were excellent: 93.3% MSTS and 97.3% EORTC. The isokinetic assessment showed a more evident strength deficit in the quadriceps of patients with distal resection, especially in the 90° flexion position of the knee.

CONCLUSIONS: The integrated gait analysis system revealed very little alterations in kinematics, kinetics and electromyography of both lower limbs. The functional recover of this ten young patients can be considered very satisfactory. The differences in the gait pattern between the two groups of patients (proximal and distal) could be due to the surgical approaches. The strength deficit showed by isokinetic assessment do not seem to modify gait pattern.

T04.P01
ANALYSIS OF THE MODEL HEMIPARETIC MOVEMENT IN SIT-TO-STANDS IN HEALTHY PERSONS IN PARALLEL BARS

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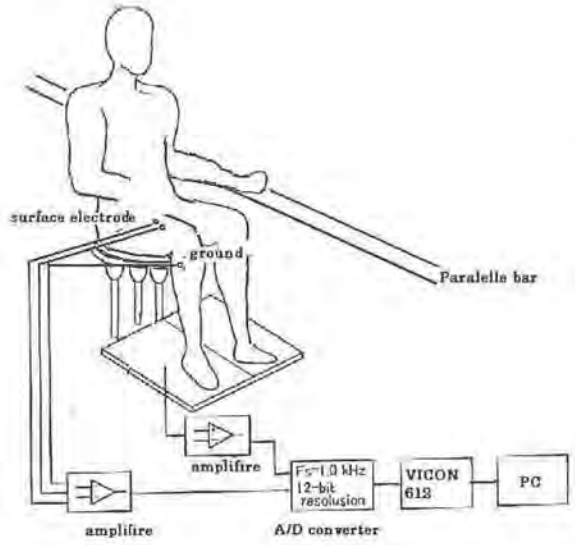
AIMS: The purpose of this study was to investigate the model hemiparetic movement in sit-to stand (STS) under the influence of seat angles in parallel bars. There are many hemiparetic clients suffering from CVA, there is few study under above situation.
METHODS: Seven healthy subjects participated in this study. Seat angles of 70, 90, 110, 130 degree were choosen. Data were gathered using a three-dimensional movement analysis apparatus (VICON 612) in addition to electromyogram (EMG).
Joint moments and muscle activities of the hip, knee, ankle joint were also measured using by the rectify-filtered EMG. Data was analyzed to the standing position starting hip the leaving clients' seats.
We have measured extension movement and flexion movement of the trunk by a three-dimensional movement analysis. EMG was also observed on the rectus muscle of the abdominal and on the erector muscle of the spine.
RESULTS: As the angle of body against the femoris, %RFEMG of the rectus abdominis muscle became increased. Other muscles were unable to give significant value.
The posterior component of joints moment was significant in every seat angles. Anterior-posterior joint moments were larger than up-down.
CONCLUSIONS: I) In comparison with angle of the body %RFEMG was increased with the rectus abdominis muscle. II) We were able to show that as increasing moment arm, %RFEMG increases in the rectus of the abdominis muscle. III) The components of perpendicular (up-down) joint movement in all seat angles were small, but anterior-posterior components were gained bigger. These were suggested the perpendicular anterior posterior components should be more bigger, components should be smaller during standing up and sitting down. Perpendicular component of joint moment is recommended bigger than anterior-posterior joint component in the view point of the smaller energy during sit-to-stand. This is also related with cultural problem.



T04.P02
PERTURBATION INCREASES RATE OF MEDIOLATERAL STANCE WIDTH VARIABILITY DURING STEADY STATE GAIT IN VESTIBULOPATHIC INDIVIDUALS

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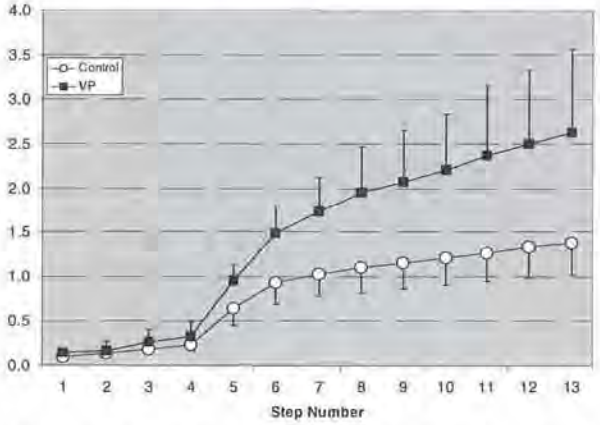
AIMS: Mediolateral foot placement is the main output parameter reflecting cns mediated balance control during gait. We have previously establsished a safe standardized gait balance perturbation protocol and demonstrated that well compensated vestibulopathic individuals (VP), with normal scores on computerized dynamic posturography, overreact to the perturbation, require more steps to recover and display increased variability in stance width, estimated from mediolateral distance between upper body (sternum) and right and left shanks, respectively. The aim of the current analysis was to investigate the rate at which this stance width parameter varied, on a step-by-step basis, during steady state gait following recovery from a mid-stance gait balance perturbation.
METHODS: Eleven healthy control subjects and eight individuals with unilateral vestibular loss (100% reduced vestibular response during caloric test) who were well-compensated (passed as normal on Equitest SOT 5 and 6) gave informed consent to participate in the study. Subjects were paced to walk at 100 steps per minute along a 12 m straight walkway with an embedded balance perturbation platform (BALDER). Perturbations that were non-thretening to overall balance were applied to the right foot in mid-stance translating it either along a 45 angle (forward and right) or in the opposite direction (rearward and left) relative to the direction of walking. Twelve perturbation and twelve control trials were presented in randomized order. Kinematic data were collected with an optotrak system using rigid body arrays with infra-red markers placed on the shanks and sternum. Stance width was normalized on a step-by-step basis to average non-perturbation trials.
RESULTS: Steady state post-perturbation behavior was different between the two groups of subjects (see graph). Linear regression analysis showed r^2 values between 0.95-0.99 across all subjects, indicating a tight linear behavior of this parameter. Linear regression slope, representing normalized step width variability rate/step, was more than twice as high in the VP group ($p<0.05$). Control subjects appeared to instantly "reset" variability rate to pre-perturbation levels, whereas VP subjects maintained an increased variability rate throughout the trial.



Step-by-step accumulated score of the mean absolute normalized deviation from non-perturbation trials for control and vestibulopathic subjects (VP). Perturbation occured on step 5.

CONCLUSIONS: Normal vestibular function appears to be required for accurate control of mediolateral foot placement during gait, especially following even gentle perturbations of the system. The parameter representing stance width variability rate may be more sensitive to vestibular integrity than some currently used clinical measures of vestibular function.

T04.P03
LOCATION FREE MOTION ANALYSIS

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AIMS: To determine accuracy and robustness of kinematics estimated from inertial sensor signals in the context of practical motion analysis. In recent years new technologies have been developed for estimating absolute 3D orientation in a global 'earth' coordinate system. Estimation accuracies of just a few degrees in the orientation of a motion sensor casing are achieved and integration drift problems are largely eliminated (sometimes at the cost of a higher sensitivity to ferromagnetic disturbances). Errors caused by ferromagnetic disturbances are decreasing with every evolution cycle of estimation methods and sensor hardware. When applying these sensors in human motion analysis errors in body segment kinematics estimation are now mainly caused by aligment inaccuracies and motion artefacts related to sensorplacement and attachment. Addressing the first issue a body segment alignment procedure based estimated helical axes is validated in detail.
METHODS: Sensors were mounted to body segments maximizing stability and alignment with bony structures was assumed fixed. 2 helical axes of the body segment were determined in the sensor reference frame from 2 recordings of single axis motion. Alternatively one of the body segment axes was determined assumning a posture with the axis parallel to the gravity vector. The 3rd axis was found assuming orthogonality For 4 sensor placements on thorax, trunk and pelvis 5 different helical axes combinations of the calibration methods were tested, each with 2 calculation order variations. They were compared against each other and against a video based motion analysis 'bony land marks' calubration method. 9 healthy subjects participated.
RESULTS: Over all subjects and segments the variation in estimated direction of the gravity vector has a mean of 0.4° (SD, ±0.2) for 5 subjects and 5 repetitions for the gravity vector and ranged from 2.4 to 6.4° for the rotation axes. The difference in direction with the axes determined by marker based data ranged from 10° to 30° with a bony landmark calibration and only 1° to 5° with the same helical axes calibration.
CONCLUSIONS: Methods were developed for 3D motion analysis applying inertial sensing technology. Application to human motion analysis seems mainly limited to the same alignment and motion artefact inaccuracies as traditional video based systems. Discussed methods of alignment calibration offer a practical solution for (out of the lab) 3D motion analysis application with a quality sufficient for many individual clinical applications. Challenges lie in application of these methods, or derivaties, for different patients groups, which are likely to produce different abilities in performing the calibration motions. An inherent direct quality check during the calibration process seems highly desired. (Clinical) users should be aware of the difference reference frames between bony land mark methods and helical axis approaches, as the axes of the latter tend to approach more the functional axes of motion. First mature practical applicatiojns for rehabilitation, ergonomics and sports start to emerge.

1] C.T.M. Baten, M.D. Klein Horsman, W.H.K. de Vries, D.J. Magermans, H.F.J.M. Koopman, F.C.T. van der Helm, P.H. Veltink, 'Estimation of body segment kinematics from inertial sensor kinematics', in submission.
2] Baten C, de Vries W, Smeding J, van Staveren G, Wassink R. Ambulatory inertial Motion analysis. The 12th annual ESMAC meeting. Marseille, France: 2003.
3] Baten CTM, Luinge HJ, Moerkerk H v.. Estimating body segment orientation applying inertial sensing. Proceedings of the Sixth International Symposium on the 3-D analysis of Human Movement. Cape Town, South Africa: 2000.

T04.P04
GROUND REACTION FORCES IN THE GAIT IN CONDITIONS OF PATELLOFEMORAL INSTABILITY

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AIMS: The normal gait is resultant of the harmonic correlation enters the coordinate action of the nervous, muscular and skeletics functions. Any conditions that disturb this harmony will be able to result in a said gait pathological, being able to bring a primary damage in the gait or to create secondary compensatory mechanisms so that this keeps a useful function. The patellofemoral instability is a pathological condition in which the reestablishment of the gait means greater functionality for the patient. The necessity appears then of the study of the biomechanical behavior of the gait of such individuals, which can optimize the diagnostic and later the proper rehabilitation.
METHODS: Participated 10 healthy volunteers, being 5 men and 5 women, and 10 volunteers with previous diagnosis of patellofemoral instability bilaterally. The volunteers had carried through two functional activities: gait in aclivity of +3° and declivity of -3° (inclinations these sufficient to unchain identification behaviors of the patellofemoral instability previously as study carried through pilot), during which they had been gotten given of the ground reaction force (System Gaitway Instrumented - Kistler, Trotter Treadmill), of the dominant member. The sampling of the ground reaction force was collected during the 10 passed of the volunteer during the continuous functioning of the treadmill. Analysis of the data had been selected, for each temporal series of the ground reaction force: a) values of the first peak of maximum vertical force (Fy1); b) second peak of maximum vertical force (Fy2); c) minimum vertical force (Fymin); d) difference between the maximum vertical force (Fy1) and the minimum vertical force (Fymin); e) value of the inclination of the curve of force until its first superior peak, called of acceptance of the weight. The data the Fy1, Fy2, and Fymin had been normalized by the corporal weight of the volunteer, and expresses for the N/kg unit. The average values of the ground reaction force had been submitted to test T of Student (two independent populations). Aimed in verifying the possibility of identification of these variables also during gait in 10 volunteers with patellofemoral instability (pathologic group). The ground reaction forces data were collected using the Gaitway Instrumented - Kistler system, which consists in a treadmill (Trotter) with two force platforms. It were studied the values of the first and second maximal vertical force peak (Fy1 e Fy2), minimal vertical force (Fymin), and the weight acceptation rate.
RESULTS AND CONCLUSIONS: The average of the variable between the groups healthful and pathological, when of the gait carried through in aclivity, it did not show significant difference. Already for the declivity gait, we have that $p>0,05$, then, also we accept the hypothesis of nullity for these variable when of the declivity gait, not having significant difference between the groups healthful and pathological. Therefore, studied dynamic variable had not presented significant differences between the groups studied during the two elect gaits in this study. For all the biomechanics variables analyzed by us in this study, we do not find anything that a biomechanics' standard in the carrying volunteers of patellofemoral instability indicated unstable during the gait carried through in aclivity and declivity. Dingwell et al., had told that the variability is indicative of the instability of the standard of motor control, and this can be a probable hypothesis for the difference found in this study not to be significant. This variable's pattern during gait in healthy volunteers and with patellofemoral instability has not shown statistically significant differences, by the Student test in a probability of 5%. So, considering the obtained results, we can conclude that such variables are not feasible to use in early diagnostic of patellofemoral instability.

T04.P05
SOFT TISSUE ARTEFACTS AND MARKERS MISPLACEMENT COMPENSATION BY MEANS OF DOUBLE STEP GLOBAL OPTIMISATION PROCEDURE

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AIMS: 3D strereo-photogrammetric reconstructions of the musculo-skeletal system and the calculation of its kinematics and kinetics via a markers-based multi-link model are strongly affected by markers soft tissue artefacts (STA) and marker misplacement. Recently a new approach named Global Optimisation Method (GOM) focusing on a multi-link chain with joint constraints has been introduced to overcome limitations of segmental optimisation methods (SOM). SOM treats each body segment separately without imposing joint constraints, thus resulting in apparent dislocations at joints. However GOM is still strongly dependent on the indeterminacy of the marker positioning step. The aim of this work is to present a new algorithm, Double Step GOM (DS-GOM) to address the reduction of both problems.
METHODS: DS-GOM represents a novel variant of the original GOM approach. A preliminary optimisation step has been introduced in order to reduce GOM dependence on the marker mispositioning. This latter, in fact, could induce erroneous estimate of the segment sizes in the kinematic chain under study affecting subsequent joint angle assessment. The underlying idea of the use of a preliminary optimisation step is to exploit the information content of measured motion (the chain moves under natural physical constraints) to optimally assess each link size in the chain. Finally the GOM approach is applied so reducing STA influence. A peculiarity in DS-GOM approach is that the first optimisation step can be feeded with multiple-gait cycles of same subject acquired along with multiple files, thus improving the consistency of the obtained results. Five different synthetic gait data samples have been created by adding different noise realisations modeling different marker mispositioning (up to ±5mm per each body landmark) and skin artefacts (up to 2.6 cm 3D oscillation) to compare DS-GOM performance with respect to SOM and GOM in recovering the true chain motion. Quantitative merit figures have been used to compare different methods outcomes.
RESULTS: By evaluating the capability to recover the true joint angle courses from noisy gait trials, DS-GOM approach presented an overall best performance producing a 12% average improvement (peak 66% ankle ab/adduction angle) w.r.t. SOM and a 6.4% average improvement (peak 47% ankle ab/adduction angle) w.r.t. GOM. In particular the preliminary Optimisation Step demonstrated to correctly address the reduction of the influence of marker misplacement in the assessment of joint centre position and bone segment sizes. It also demonstrated to be repeatable, statistically robust, consistent and unbiased. SOM approach demonstrated to be affected by a joint dislocation phenomenon of a magnitude up to 2.91 cm, not present by default in both GOM and DS-GOM. The full optimisation process time on each synthetic noisy gait trial (including two strides sampled at 100 Hz, totally 147 frames) was around 15 sec. on a Athlon XP 2800+ desktop PC.
CONCLUSIONS: The DS-GOM method was shown to correctly address critical inaccuracies induced by STA and marker mispositioning. The uniqueness of the DS-GOM procedure relies on its capacity to achieve optimal solutions by taking advantage of information content in motion data. Further the more are the data (i.e. multiple gait cycles along with different data recordings) the better are the optimisation results. The DS-GOM approach has been developed to be compliant with time and processing resources usually available in a movement/gait analysis lab and has been demonstrated to provide a useful processing tool which can be routinely adopted.

T04.P06
COMPARISON OF TECHNIQUES FOR UPPER TRUNK MOTION IN GAIT ANALYSIS

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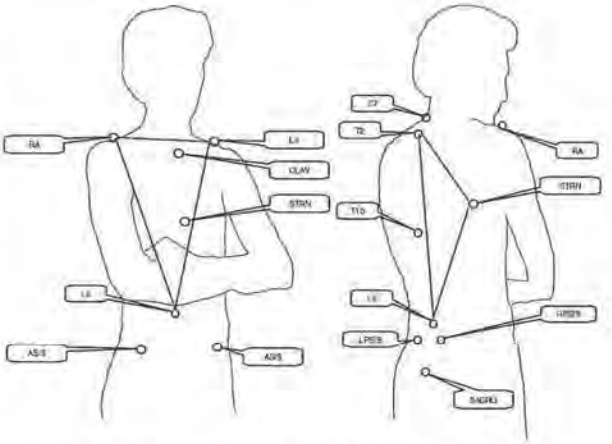
AIMS: In gait analysis a little attention has been given to technically reliable and clinically consistent techniques for quantitative measurements of upper trunk rotations. Current motion analysis systems enables more comprehensive, though more complicated, marker sets and data reductions. Errors related to accuracy should be addressed with a rational marker set, errors related to repeatability should be investigated by analysing carefully reference frame definitions. Quantitative comparison of possible protocols is fundamental for future trunk motion analyses.
METHODS: Several techniques were tested, those from the literature and those after possible improvements. These involve very different sets of markers and have either a frontal- or a sagittal- plane-based first definition of the trunk anatomical reference frame. A volunteer was analysed with a complete 12-marker set (5 on pelvis, 7 on trunk), suitable to process all these techniques. Gait and isolated and known rotations between these two segments were collected. The entire session was repeated on the same subject as performed by 5 different operators. Trunk to pelvis motion was analysed by the standard Grood and Suntay convention, following a single standard definition for the latter and the different techniques for the former.
RESULTS: Time-history of flexion, axial rotation, and lateral bending differ considerably, i.e. up to 15 degrees, among the techniques. Anatomical reference frames based on closer markers are much less repeatable.
CONCLUSIONS: For upper trunk rotations, markers must be located in well identifiable landmarks, anatomical frame definitions must minimise errors associated to marker misplacement and artefactual motion, therefore the largest possible areas should be covered by the markers. Frontal-plane-based first definitions, i.e. based on acromion markers, enables reliable axial rotation, but flexion and lateral bending are affected by undesired scapula motion. Sagittal-plane-based first definitions, based on sternal and vertebra markers, enable reliable lateral bending, but flexion and axial rotation are more critically determined. Either a combination of the two approaches or a selection according to the specific clinical interest should be adopted.



A volunteer with the marker set utilised for this investigation

T04.P07
A QUANTIFIED ANALYSIS OF ELECTRICAL ACTIVITY IN THE LEGS DURING WALKING AND JOGGING

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AIMS: The aim of this study was to analyse the electromyographic activity from muscles of both legs during walking and jogging in barefoot young adults.
METHODS: 10 university students have participated voluntarily in the study. 10 successive recordings in door and overground were made: 5 walking and 5 jogging. 8 footswitches B&L enabled the stride phases to be identified. Six muscles of each leg were tested: Rectus Femoris (RF), Vastus Medialis (VM), Tibialis Anterior (TA), Biceps Femoris: long caput (BF), Semitendinousus (ST), Gastrocnemmius Lateralis (GL). Electrical activity was registered by means of a MA200 Motion Lab system and active surface electrodes. Sampling rate was of 3000Hz. Support and non support phases were represented as percent of cycle time. The electromyographical activity, Grand Ensemble Average (GEAV) of LE was expressed as: 1) normalised by rapport to maximal amplitude (Winter 1984) and 2) absolute values.
Statistics Analysis: space-temporal parameters and increments of peak activity were analysed by t-Student. An ANOVA of two factors was used to compare the EMG signal by intervals of 10% of Locomotion Cycle (LC) ($p<0,05$).
RESULTS: The average speed for walking was 1,33±0,12 ms^{-1} and 2,50±0,31 ms^{-1} for jogging. Significantly the cycle time and support phase decreased and non support phase increased. During jogging the muscle activity, expressed as normalised signal, increased in all muscles ($p<0,05$). Some muscles did not present significant differences on all intervals. The muscles of right leg presented more intervals with similar activity level in both modes of locomotion. Left RF had not any differences of activity on the intervals 40-50% and 60-70%, and Right RF on the intervals 50-60% and 60-70%. Intervals 40-50% and 50-60% correspond in walking to the support phase and in jogging to the initial flight and to the beginning of swing respectively. Interval 60-70% corresponds to the swing phase in both modes of locomotion. In the Right VM, intervals of 20-30% and 50-60% did not present significant differences. Left and Right TA in walking and jogging showed similar activity on the interval 70-80% corresponding to the swing phase in walking and jogging. Right TA also presented similar activity on the interval 0-10% or loading phase. The Right BF had not any activity significantly different at the interval 20-30% of LC or midstance. Left GL had non activity significantly different at interval 50-60%, corresponding to pre-swing in walking and initial flight in jogging. Peak of activity: in walking and running the VM had a peak of Lineal Envelope bigger than the RF. In the jogging the VM showed the most dramatic increase of all muscles analysed. RF belonging to same muscle group showed an increase smaller. The GL showed also an important increment. BF of both legs presented a peak bigger than the ST, their activity increases of similar mode but the BF continues beginning more active in the jogging. The peak of TA was the bigger during walking but his increment in jogging was smaller that VM and LG. The increment for the activity of thigh muscles was similar of both legs but the increment of leg's muscles: TA and LG was different, the increments were bigger in the left leg. Time of peak activity: for the thigh muscles remains in the same phases in both modes of locomotion, for the leg muscles the time of peak changed.
CONCLUSIONS: Comparisons of muscle activity between two modes of progression reveal the adaptability of neuromuscular processes to bigger mechanical needs.

T04.P08
A COMPARISON OF KINETIC GAIT PARAMETERS FOR 3-13 YEAR OLDS

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AIMS: Normative gait data is essential for diagnosing and treating abnormal gait patterns. A lack of normative pediatric data in the literature often results in comparisons to adult normative data. While gait kinematics of children aged 3½ to 4 years are considered to be adult-like [1], it is unclear when children achieve adult-like kinetic patterns. The purpose of this study was to identify age-related differences in kinematic and kinetic gait parameters across children aged 3-13 years old.
METHODS: Forty-seven (n=47) children aged 3-13 years old were recruited to participate in the study [ages 3-4 years (n=13); ages 5-6 years (n=10); ages 7-8 years (n=12); ages 9-13 years (n=12)]. A six-camera Vicon 512 motion capture system (ViconPeak) and three force plates (Kistler Instruments) were used to track segment kinematics and ground reaction forces. Anthropometric data was estimated using the elliptical cylinder model [2]. Kinetic parameters, such as joint moments and power were computed using an inverse dynamics approach. A multivariate analysis of variance was used to test for significant differences in the mean peak value of kinematic and kinetic gait parameters between the four age groups.
RESULTS: Significant differences in cycle time, cadence, and walking velocity were observed between age groups ($P<0.002$). No significant differences in hip, knee or ankle joint angles were observed between any of the age groups. Significant differences in joint moments between age groups were observed at the hip, knee, and ankle. The peak hip flexion moment was significantly smaller in the 3-4 year olds (-0.26±0.21 Nm/kg) compared to children aged 9 yrs or older (-0.46±0.17 Nm/kg) at mid-cycle ($P<0.05$). Similarly, the peak knee extension moment was significantly smaller in the 3-4 year olds (0.15±0.15 Nm/kg) compared to children aged 9 yrs or older (0.36±0.22 Nm/kg) during early stance ($P<0.01$). The peak ankle plantarflexion moment was significantly higher in children aged 9 yrs or older compared to all other age groups ($P<0.0001$). In addition, the peak moment at the ankle in the 3-4 year olds (0.93±0.16 Nm/kg) was significantly lower than the 7-8 year olds (1.19±0.21 Nm/kg) during late stance. No significant differences in hip or knee joint power were observed between any of the age groups. However, peak power absorption (A1) at the ankle was significantly higher in children aged 9 or older compared to all other age groups ($P<0.0001$). In addition, peak power generation (A2) at the ankle was significantly higher in children aged 9 or older (2.99±0.20 W/kg) compared to the 3-4 yr olds (2.13±0.22 W/kg body weight) and the 5-6 year olds (2.11±0.27 W/kg) during late stance.
CONCLUSIONS: Kinematic differences between age groups were similar to previous work [1]. With the exception of the ankle joint, children attained adult-like gait kinetics by five years of age. Mature sagittal kinetic patterns at the ankle were not observed until approximately 9 years of age and older. These results suggest that age-matched normative data must be used in clinical gait analyses. Age-related differences in ankle joint moments and power suggest that children lack the neuromuscular maturity to produce adult-like ankle patterns.

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[2] Jensen, R. K., 1978. Journal of Biomechanics 11, 349.

T04.P09
MARKERLESS EVALUATION OF SIT-TO-STAND STRATEGY IN GAUSS-LAGUERRE DOMAIN

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AIMS: The Sit-to-Stand (STS) analysis is generally performed through the use of force platforms and marker-based systems (1). Marker-based systems have a high levels of accuracy but show some drawbacks that can be overcome by the use of video systems applying markerless techniques. In this paper, a specifically designed markerless method for evaluating the STS kinematics is presented.
METHODS: A Maximum Likelihood method for the 2D markerless

detection and tracking of relevant body points, working in the Gauss-Laguerre Transform (GLT) domain (2), is presented. The GLT is based on an orthogonal family of Circular Harmonic Functions, which permit optimal estimation of the position of a relevant point looking at the maxima of a "Gauss-Laguerre Likelihood Map". In this work a large number of points have been manually selected close to joints, and then they have been automatically tracked for reconstructing a human body model and estimating the hip and ankle angles over time (respectively called α and γ). The strategy used to stand up (forward flexion or limited flexion) is evaluated by analysing α_{min}, representing the maximal trunk flexion, and γ_{min}, representing the leg flexion during each STS task.

RESULTS: Results are obtained by analysing videos from a commercial camera: the sequences capture human STS in the sagittal plane. The proposed motion estimation technique is applied with specific attention on the junctions involved during the gesture and allows to evaluate and reconstruct joint kinematics. Preliminary results provide high level of tracking accuracy. Figure 1 shows 2D joint kinematics estimated from the barycentre of a 10-point trajectory for each junction-area and the value of α and γ over time. The values α_{min}=45° and γ_{min}=63° show that the subject has used a limited flexion strategy in order to stand up.

CONCLUSIONS: In this paper, the proposed 2D markerless method for evaluating the STS kinematics is described. Results show high level of tracking accuracy and the possibility to evaluate the strategy used to stand up. Performance will be completely illustrated by several experimental results and comparison with marker-based methods found in literature (3).

1) Kerr, K. M., White, J. A., Barr, D. A., Mollan, R. A. B., "Analysis of the sit-stand-sit movement cycle in normal subjects", Clinical Biomechanics, 12, 236-245, 1997.
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3) M. Galli, M. Crivellini, "The effect of muscular strengthening with electrical stimulation on sit-to-stand motion in young and elderly persons", IEEE Engineering in Medicine and Biology Society, Vol. 20, No 5, 1998.

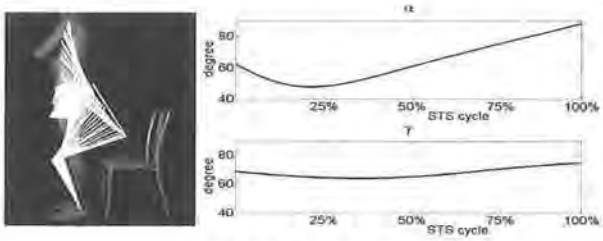

FIGURE 1: First results

T04.P10
ROLLOVER SHAPE OBSERVATIONS FROM FOUR ANKLE-FOOT PROSTHESES

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AIMS: This study compares the rollover shapes of various prosthetic limbs to the natural limb. An ankle-foot rollover shape is the effective rocker shape that ankle-foot conforms to between initial heel strike and opposite heel strike [1,2,3,4]. Previous work has shown that using an inverted pendulum as a model, a person's ideal rollover shape for both limbs have a radius of 19% of their total body height [2]. Published tests performed to date have either been with fully limbed subjects or a simulation of prosthetic feet use using a prosthetic foot loading apparatus [1]. A more clinical view of the ankle-foot rollover shape from a prosthetic foot is required.

METHODS: In this study, four prosthetic feet were characterized for their rollover shape; Otto Bock LuXon Max DP, Ossur Ceterus, Ossur Talux category 6, and Ossur Talux category 7. A single subject with a trans-tibial absence was recorded as they crossed a force plate in a motion lab. The rollover shape is a transformation of the lab-based coordinates into a shank-based coordinate system.

RESULTS: Results from this study have shown that the averaged rollover shape radii over 5 trials from the trans-tibial limb and natural limb are 17.6% and 23.45% (LuXon Max DP), 13.6% and 21.2% (Ceterus), 14.7% and 21.8% (Talux category 6) as well as 15.8% and 27.3% (Talux category 7).

CONCLUSIONS: When compared to the corresponding rollover shapes from the natural limb for each trial, the results indicate that the characteristics of each foot have a direct effect on the natural limb's rollover shape.

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[4] Hansen, A.H., et al. J. Biomech. 37 (2004): 1467-1474.

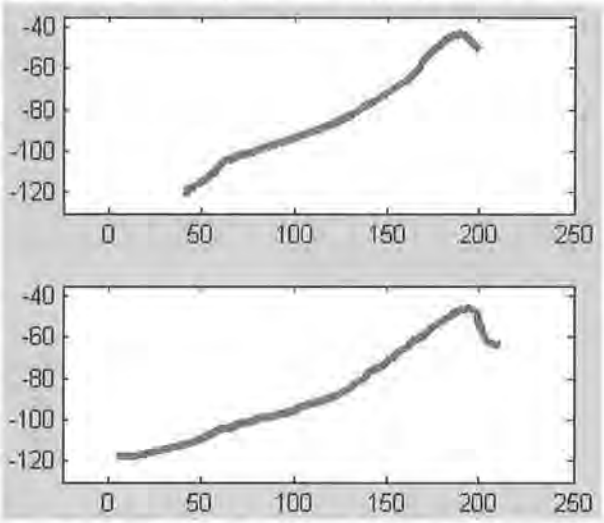

Figure 1 - Rollover Shapes from LuXon Max DP (top) and natural limb (bottom)

T04.P11
PRINCIPAL COMPONENT ANALYSIS OF DISTAL RADIAL FRACTURE KINEMATICS DURING CYCLIC ACTIVITIES OF DAILY LIVING

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AIMS: To detect discriminant features in the cyclic kinematic patterns generated during selected upper limb activities of daily living by a normative and a distal radial fracture group, so as to reduce the multidimensionality of the kinematic analysis.

METHODS: Cyclic activities of daily living were performed using a protocol that allowed comparison between the resulting kinematic patterns or waveforms. A group of 11 subjects with normal hand function (group A) was selected as normative group (average age: 31.5ys, SD: 8.7ys; 8 right-dominant and 3 left-dominant). A group of 5 subjects having undergone treatment for distal radial fracture (group B) was also tested using the same methods (average age: 34.2ys, SD: 16.8ys; 4 right and 1 left distal radial fracture). The key-turning task is presented here, which was performed by turning a key 90° clockwise. Principal component analysis (PCA) was applied to the waveforms of group A, using the procedure illustrated by Deluzio et al., 1997 (Human Movement Science, 16, 201-217) for gait patterns. A 90% trace criterion was used to calculate the number of principal components (PCs) to retain.

RESULTS: Results are presented for elbow pronation/supination (PS). Two PCs were retained, whose relative y-scores are plotted in Figure 1. The first component consisted of a simple pronation pattern. The opposite signs of Y1 differentiated left-hand users (utmost right), who required pronation to rotate the key, from right-hand ones, who required supination, with the exception of subject 3 group B. The second component consisted of pronation (cycle first half) followed by supination (second half). Subject 3 stood out because of limited elbow supination, which resulted from the combination of pronation (Y1) and supination (Y2) components.
CONCLUSIONS: Upper limb analysis can employ the statistic tools of gait analysis provided a cyclic and repeatable protocol is used. PCA was applied to elbow PS to identify statistically different movements of the distal radial fracture group and underline their main characteristics. This is particularly important in the presence of a large data group, when the identification and evaluation processes need to be both rapid and accurate. Limited PS was identified as a discriminant feature, supporting the follow-up studies for this injury that measured a reduction of PS by about 80% compared to that of the unaffected side. The cycle stages concerned can be identified on the basis of the contribution given by each component.

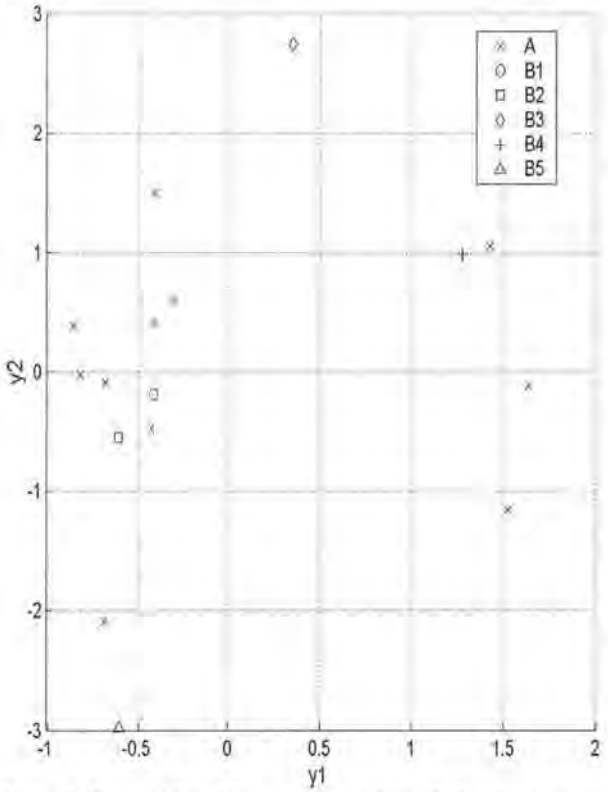

Figure 1. Y-scores plotted for group A and B for the key-turning task. Angle: Elbow pronation/supination.

T04.P12
ESTIMATION OF KNEE CRUCIATE LOADS DURING LIVING ACTIVITIES: STEP UP/ DOWN AND CHAIR RISING/SITTING MOTOR TASKS

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AIMS: The modelling approach is the only possible way to estimate the biomechanic function of the different anatomical sub-structures of the knee joint in physiological conditions. The aim of this study was the estimation of the forces in the anterior and the posterior cruciate ligaments, ACL and PCL respectively, in order to evaluate their passive stabilization contribution during the execution of daily living activities.
METHODS: Subject specific geometries and kinematic data were the foundations of the 3D quasi-static model adopted. A cruciate ligaments model, using 25 elastic-linear elements, was implemented taking the anatomical twist of the fibres into account. the model was characterized by subject specific geometrical parameters obtained from nuclear magnetic resonance. The anatomical cruciate force components were estimated during step up/down (SUP) and chair rising/sitting (CRS) motor tasks.
RESULTS: The global behaviour of the PCL showed little forces from the extension to a variable angle of 20°-40° of flexion, a following increasing of forces until reaching the maximum, at about 70° of flexion, and an occasional decreasing, Figure (a-d). Nevertheless different curves of force versus flexion angle were obtained between the two motor tasks. Double medial-lateral (M/L) component forces were estimated in the SUP with respect to the CRS motor tasks. Higher repeatability during SUP was obtained in the extension movements (SUP_Ext), Figure (a), whereas repeatability during the CRS was fairly good in both CSR movements, Figure (c-d). Regarding the ACL, instead, null forces were always noticed.
CONCLUSIONS: A 3D quasi-static model of ACL and PCL was implemented using geometrical parameters and kinematics data from a single living subject. The inactivity of the ACL was due to the typology of both movements, those tend to slack the ACL and to stretch the PCL. Regarding the PCL, the higher repeatability obtained during the SUP_Ext, Figure (a), was probably due to a major activity of the muscles for controlling the movement. These had the goal to perform the movement against the gravity force and their concentric contractions were more controlled by the nervous system. During the SUP_Flex the eccentric contraction of the muscles, needed to control this movement in according to the gravity, was less controlled and a minor repeatability was obtained, Figure (b). In CSR tasks smaller forces were calculated with respect to those obtained in the SUP. This was explainable to the typology of the movement, indeed, using two legs, smaller stabilization contribution was required to each ligament, in particular in the M/L direction. In conclusion the devised model was effective in evaluating loads in the ACL and PCL during the execution of daily living activities.

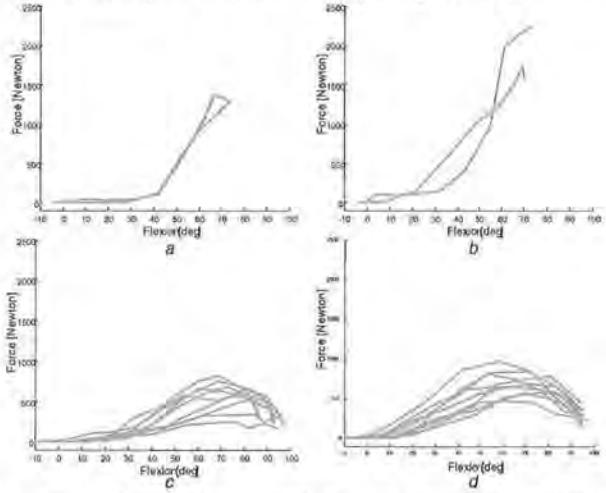

Figure: M/L forces of PCL versus flexion angle: 2 repet. of SUP_Ext (a) and SUP_Flex (b), 9 repet. of CSR_Ext (c) and CSR_Flex (d)

T04.P13
COMPARATIVE ELECTROMYOGRAPHY ANALYSIS OF THE EXTENSION OF LEG DURING GAIT IN A CARRIER OF LEGG - CALVÉ - PERTHES (DLCP) INSIDE AND IS OF THE WATER

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AIMS: Compare the electric active of femoral quadriceps, vast medial oblique and vast lateral during inside and outside the water in the patients have DLCP.
METHODS: *Casuistry:* Carry out a project needs really an study the case an the person is 11 years old, male, h has the Legg - Cave - Perthes, and actually receive physiotherapy treatment in the ground and water, 2 times a week.
Procedure: We start the project, the patient know the procedure and the methodology this project. All the claim went in the member dominant. By means of the surface electromyography, two electrodes had been connected to catch the electric activity in the muscular wombs of the following muscles: femoral, vast rectum medial oblique and vast lateral. The patient was guided to walk a distance of 5 m and 30 cm inside and is of the water, being that in the water the Bio Oclusive® was used (protection of the electrode) that it does not intervene with the execution of the requested task. The march inside of the water was carried through in a hydrotherapy swimming pool with the average temperature of 33°C, with immersion to the level of the xifoid process. The analysis of the data was made by means of the values of the average curve of the electromyography of surface. The sEMG equipment was MIOTEC - MIOTOOL 440 with 4 channels.
RESULTS: The following results had been gotten: Vast Medial Oblique in ground 35,2 μv; in water 25,2 μv; Vast Lateral in the ground 49,3μv; in water 32,4 μv, Femoral Rectum in ground 52,3 μv, water 41,8 μv.
CONCLUSION: The values suggest that for the analyzed individual a reduction of the electric activity of the muscles of the water when compared with the same muscles in the activity carried through in the ground occurred inside.

T04.P14
MRI ANALYSIS OF FLEXION MOVEMENT OF THE SHOULDER JOINT

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AIMS: Flexion of the shoulder joint on a sagittal plane involves internal rotation of the humerus. Internal rotation has been believed to occur with release of the coracohumeral ligament from its tension accompanying the flexion, but the degree of internal rotation or any other factor involved with internal rotation is not clear. Passive flexion movement of the shoulder joint in a sagittal plane was experimentally analyzed by magnetic resonance imaging (MRI) that is not invasive to human body.
METHODS: The subjects were 8 healthy men (mean age: 21.3 years) whose consent about the experiment was obtained. They were instructed to do passive flexion movement of the right shoulder joint on a sagittal plane in a left lower lateral recumbent position at 5 static angles (0°,90°,120°,150°, and maximum flexion). In MRI (SIGNA 1.5 T, GE Co.), proton-density weighted images of the scapula were taken by a radiological technician in approximately 46 2-mm slices that were prepared in parallel with a scapular plane. The parameters measured at each static angle were: flexion angle of the long axis of the humerus (arm angle: Angle A); upper rotation angle of the scapula (scapular angle: Angle S); capital angle of a line, which connects the great tubercle of humerus at 0° and the angle of maximum flexion with the center of the humeral head, with a frontal plane.
RESULTS: The mean values of Angle A measured at the static angles were approximately 0°,90°,119°,144°, and170°, respectively. On this occasion, the mean values of Angle S were approximately 9°,35°,45°,53°, and 61°, respectively. The capital angle at 0°, i.e., retroversion angle, averaged 30.4°, showing that the great tubercle of humerus was located anterolaterally. The capital angle at 170° averaged -27.2°, showing that the great tubercle of humerus was located posteromedially.
CONCLUSIONS: Based on the capital angles, the following is estimated: the movement axis of the flexion of the shoulder joint on a sagittal plane is the frontal horizon; flexion of the shoulder joint on the frontal horizon makes the great tubercle to be oriented posterolaterally (-30.4°) at the angle of maximum flexion and internal rotation of the shoulder joint does not occur. Actually, however, the great tubercle was located posteromedially (-27.2°) at the angle of maximum flexion. In other words, the great tubercle is to be oriented posteromedially (-27.2°) at the angle of maximum flexion on the frontal horizon following internal rotation at 122.4°(=180°-30.4°-27.2°) at flexion angle 0°. Accordingly, internal rotation at approximately 120° ultimately occurs with flexion movement. Furthermore, the tracing between the point of contact of the supraspinous muscle with the glenoidal cavity and the great tubercle insertion indicates the direction of decrease in the muscle to the shortest length. When thus considered, the supraspinous muscle is estimated to have an action to induce internal rotation accompanying flexion, as well as conventional actions to induce abduction of the shoulder joint and to press the bone head against the acetabulum.

T04.P15
STUDY OF THE MOTOR BEHAVIOR OF HEALTHFUL VOLUNTEERS AND AFTER STOKE DURING THE GAIT

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AIMS: Stroke's sequels, as the spasticity, can modify the joint moments during the dynamic gait. It is important to measure the standard of muscular electric activation which had the relation of the spasticity in modifying the balance of the agonist and antagonist muscles during the dynamic gait, as well as the stretching reflexes, that can, therefore, to modify the biomechanics of the gait of these patients. The purpose of this study was to compare muscle activity and joint moments in the lower extremities during walking between subjects with stroke and control subjects.
METHODS: After approval of the work for the Committee of Ethics in Research, the data had been collected of 15 after stroke volunteers and 15 healthful volunteers. For capitation of the electric activity of the muscles the EMG was used, beyond one electrogoniometer, on the axis to articulate of rotation of the joint of the ankle in study, connected to a conditioning module of signals. The surface electrodes had been placed on the motor point of the medial gluteus, rectus femoris, tibialis anterior, soleus and medial hamstring of the spastic side. After the treatment of the signal, an average tracing of the complete cycle of the gait was gotten, being representative of the functional activity of the muscle of each volunteer. Finally, a representative average tracing of the functional activity of the volunteers of the sample was gotten and submitted to the analysis comparative statistics, between the analyzed muscles. In relation to electrogoniometer, the system was programmed to express its values of variation of the electric tension converted, for calibration, in degrees of movement to joint, during the movement of the connecting rods, and that it was used to measure the movement of flex-extension of the joint of the ankle during the gait, where the neutral position of the joint of the ankle must be equal to 0°. Onset and cessation times of lower extremity electromyographic (EMG) activity and joint moments were determined. Onset times with respect to heel-strike for the medial gluteus, tibialis anterior, soleus, rectus femoris and medial hamstring muscles were significantly earlier during the gait cycle in subjects with stroke than in control subjects.
RESULTS and CONCLUSIONS: Onset electromyographic activity with respect to heel-strike for the medial gluteus, tibialis anterior, soleus, rectus femoris and medial hamstring muscles were significantly earlier ($p<0.05$) during the gait cycle in subjects with stroke than in control subjects. Already the end of the electromyographic activity for the muscles rectus femoris, tibialis anterior, soleus and medial hamstring significantly ($p<0.05$) had been delay in the subjects with stroke. Different moments of electromyographic activation during the gait, particularly in the joints of the knee and ankle, in hemiparetics patients, as sequel of brain vascular disease, compared the healthful volunteers the

spasticity of the affected member is justified in theory the spasticity of affected member. This characteristic of the motor behavior of the spastic's muscles is consistent with the findings of our previous studies and other authors. The cessation times of soleus, tibialis anterior, rectus femoris, and medial hamstring muscles were significantly prolonged in subjects with stroke. Subjects with stroke showed more co-contractions of agonist and antagonist muscles at the ankle and knee joints during stance phase compared with control subjects. These gait changes and co-contractions may allow subjects with stroke to adopt a safer, more stable gait pattern to compensate for diminished sensory information from the ankle.

Movement disorders

EFFECTS OF SCALING FROM NARROW TO WIDE STANCE ON VOLUNTARY STEP INITIATION IN PARKINSON'S DISEASE

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AIMS: Parkinson's disease (PD) was found to impair the adaptive scaling of postural responses to changes in external perturbations [1]. The present study aims to investigate the effects of PD and Levodopa on adaptive scaling of postural preparation for a voluntary movement in different initial stance conditions. To this aim we investigated scaling of anticipatory postural adjustments (APA) for step initiation when stance conditions changes from a narrow to a wide stance.
METHODS: SUBJECTS: 11 subjects with PD and 17 age-matched control subjects were included in the study. PD subjects were tested both off levodopa (after a 12 hours washout) and on levodopa (about 1 hour after taking the medication in their usual dosage). PROCEDURE: subjects were asked to take a voluntary step, starting with feet on a double-plate force platform both from a narrow Stance (feet 5 cm apart) and from a wide Stance (feet 26 cm apart), performing 3 consecutive trials in each condition. DATA ACQUISITION AND ANALYSIS: we acquired force-platform data (sampled at 480 Hz and low-pass filtered at 50 Hz), kinematic data (sampled at 60 Hz, Motion Analysis, Santa Rosa, CA). The APA magnitude was quantified by the peak of the lateral centre of pressure (CoP) excursion from the baseline. Length and velocity of the first step were measured by means of reflective markers placed on lateral malleolus, to quantify the kinematics of the stepping phase.
RESULTS: High responsiveness to levodopa of PD subjects was verified by the UPDRS- Motor section that significantly improved from off to on (mean±SEM: 41.15±3.84 in off, 23.5±3.38 in on). APA MAGNITUDE: PD subjects present inadequate APA in both narrow and wide stances, compared to control subjects (see figure); levodopa increases APA in both stances, but restores normal APA only in narrow stance. SCALING APA: Comparing APA in narrow and wide stance, unlike control subjects, PD subjects off levodopa do not scale up the magnitude of APA (as shown in the figure). Levodopa significantly improved PD subjects ability to scale up the magnitude of APA. STEPPING PHASE: PD subjects showed reduced length and velocity of the first step compared to control subjects in narrow and wide stance. Levodopa improved more step velocity than step length both in narrow and wide stance.
CONCLUSIONS: Subjects with PD have more difficulty initiating a step from a wide stance than from a narrow stance. Small APA scaling in PD off may also indicate the inability of PD subjects to quickly adapt to initial stance conditions, unlike control subjects that increased the magnitude of APA for the wide stance. PD subjects, both off and on levodopa show smaller deviation from normal APA for step initiation in narrow stance than in wide stance. Our results showed that levodopa improves ability to adapt APA for step initiation to stance width and confirmed that levodopa helps to increase the magnitude of APA [1] close to normal values, and to increase velocity and length of the first step.

[1] Horak FB, Frank J, Nutt J. "Effects of dopamine on postural control in parkinsonian subjects: scaling, set,and tone", J Neurophysiol. 1996.

CORTICOMOTOR FACILITATION IN THE QUADRICEPS: A COMPARATIVE STUDY IN YOUNG, OLD AND PARKINSON'S DISEASE (PD) SUBJECTS

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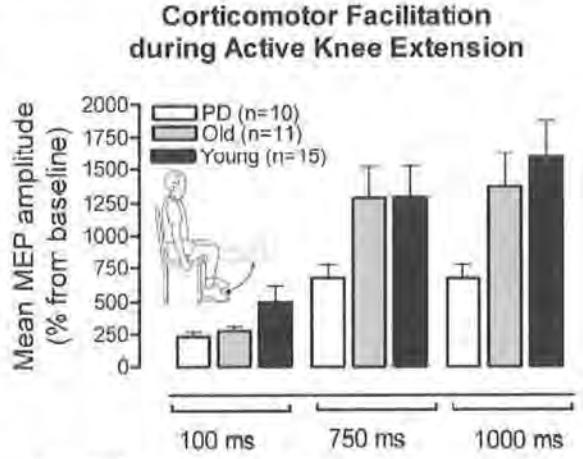
AIMS: To study the time course and the magnitude of corticomotor facilitation in the quadriceps muscle (Quad) during active knee extension in healthy subjects, both young and old, and in patients with mild PD.
METHODS: Participants (Young, n=15, 23±2 years; Old, n=11, 57±7 years; PD, n=10, 60±7 years) underwent transcranial magnetic stimulation (TMS) of the left motor cortex while performing an active knee extension movement (from 90° to 180°) in response to an auditory signal (1250 ms duration). TMS was delivered at three time delays in the course of the movement: 1) before initiation (100 ms delay), 2) while the knee moved into mid-range (750 ms delay), and, 3) near the end of the extension (1000 ms delay). To avoid anticipation, TMS delivery was varied pseudo-randomly across the three time epochs until 5-10 responses were collected at each time delay. Corticomotor excitability was assessed by monitoring changes in the amplitude of motor evoked potentials (MEPs) measured during contraction relative to baseline values (MEPs at rest).
RESULTS: At baseline, PD patients exhibited significantly ($p=0.01$) larger MEPs in the Quad (mean 168 μV) as compared to healthy subjects both young (mean 80 μV) and old (mean 76 μV). During contraction, all subjects displayed a sharp build-up in corticomotor excitability from early initiation (100 ms delay) to near movement completion (Figure). Accordingly, the factor "Time" came out as very significant in the ANOVA ($F=26.1$, $p<0.001$). The ANOVA also revealed a significant "Time X Group" interaction ($F=3.1$, $p=0.02$). In fact, PD patients exhibited consistently lower levels of facilitation at all time delays than the two other groups (Figure). Post-test analysis confirmed that corticomotor facilitation at 1000 ms was significantly higher in young and old, as compared to, PD subjects.
CONCLUSIONS: In the early phase of knee extension, corticomotor excitability rises very sharply in the Quad, probably reflecting the increase in the number and magnitude of descending volleys. As the movement proceeds, corticomotor excitability continues to rise, as additional input reach the motoneurones through re-afferences. The impaired ability of PD patients to facilitate the Quad in the context of active contraction may arise from an increase in corticomotor excitability already present at rest (large MEPs) along with a failure to energize the voluntary drive due to the dysfunction in the cortico-striatal basal-ganglia loop.

This work was made possible partly through support by NSERC (Canada) to F Tremblay.



Mean MEP amplitude changes in the three groups expressed as % from baseline (resting condition)

QUANTITATIVE EVALUATION OF LOCOMOTOR FUNCTIONS IN PATIENTS IN THE EARLY STAGES OF PARKINSON S DISEASE

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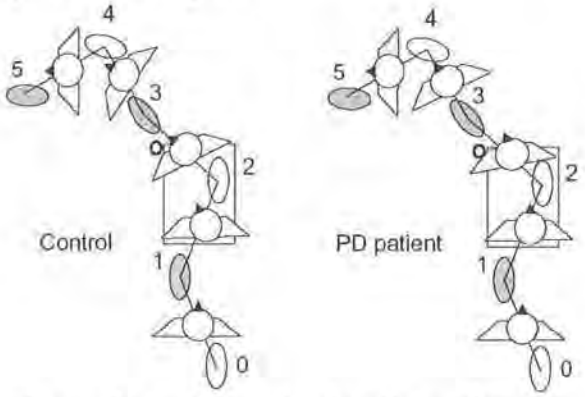
AIMS: It is well known from literature, that severe PD patients (H&Y >=3) are affected by consistent impairments of the principal locomotor functions, such as steady-state walking [1], gait initiation [2] and turning around an obstacle [3]. The aim of the present study was to investigate the presence of these alterations also in patients in the early stages of PD (H&Y<=2), in order to find out markers useful for a precox diagnosis of Parkinson s disease.
METHODS: Seven mild idiopathic PD patients (H&Y<=2) and seventeen control subjects were assessed by multifactorial analysis of kinematic and kinetic variables, during the execution of 3 different tasks: 1) Steady-state walking; 2) Gait Onset; 3) Turning around a corner during walking. Numeric parameters representative of each task were automatically computed and the differences between the control and the PD groups were analysed by means of Mann-Whitney U-test.
RESULTS: PD patients didn t differ from control group in steady-state walking. On the contrary, significant differences were shown in the other two tasks. In particular, in gait initiation, PD showed a reduction of the CoP backward displacement typical of the imbalance phase, a prolongation of the swing phase and a reduction of the first step length and gait velocity. As for the turning task, control subjects started turning the head in the new direction already during the approach step which preceded the first turn step, and, after a delay of about 150ms, started trunk reorientation, adopting a typical top-down strategy. PD patients, instead, started turning the head together with the trunk and only during the first turn step, thus later with respect to controls. Moreover, the magnitude of head and trunk rotations was significantly lower during either the approach step and the first turn step. The two turning strategies are schematically represented in the Figure.



Scheme of the turning strategies adopted by controls and PD patients. 1-2: approach step; 2-3: first turn step

CONCLUSIONS: Patients in the early stages of PD, didn't revealed, during steady state walking, the consistent impairments of kinematics and kinetics typical of severe PD patients. Whereas, significant alterations were noticed in transient situations such as change of direction and gait onset. These results suggest that the quantitative analysis of locomotor tasks which imply the transition from one condition to another, could provide parameters useful for the characterization of PD patients also in the early stages of the disease.

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[2] Burleigh-Jacobs A et al, Step initiation in Parkinson s disease: influence of levodopa and external sensory triggers, Mov Disord. 12(2):206-15, 1997
[3] Morris ME et al, The biomechanics and motor cont rol of gait in Parkinson's disease, Clin Biomech. 16:459-70, 2001.

DIAGNOSING PATIENTS WITH ANTERIOR KNEE PAIN

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AIM: Pain in the anterior region of the knee is one of the most common musculoskeletal complaints in children, adolescents and young adults. Although the etiology of anterior knee pain (AKP) is not entirely clear, the most commonly accepted hypothesis is related to abnormal patellar tracking, which increases patellofemoral stress and subsequent articular cartilage wear. AKP often results in inactivity and immobilization. Patients with AKP manifest various compensation strategies especially when they walk. Our aim was to look for correlations between the resulting muscle weakness and its corresponding gait kinematics in order to achieve a better prognosis.
METHODS: Ten patients between the ages of 18 and 25 (mean 20) with a diagnosis of unilateral AKP with mean symptoms of 4.8 month consented to participate in this study. Subjects were excluded from the study if they reported having previous knee surgery, prior fracture of the affected limb, metabolic disease or a history of traumatic patellar dislocation.
The affected (study) leg was compared with the patient's unaffected (control) leg. The patients were first tested on an isokinetic dynamometer for static and dynamic strength measurement for both knees. Following the subjects performed limits of stability (LOS) test while standing on a force platform by leaning with straight body in antrio-posterior and medio-lateral directions. The subjects then performed several bouts of self paced gait along instrumented 10 meter walkway which included a camouflaged force plate and pair of hi-speed video cameras. Throughout the tests the surface EMGs of the bilateral vastai; [vastus medialis (VM), and vastus lateralis (VL) were recorded. For data analysis, the EMG was rectified, averaged and normalized in time over MVC obtained in the dynamometer. Motion analysis software provided the knee kinematics and moments based video and on ground reaction forces.
RESULTS: The mean thigh circumference of the study knees was 45cm in comparison to 47cm of the control knees was found to be significant ($p < 0.01$). However, the study knee was stronger, both, in static (60 deg/sec) and dynamic (180 deg/sec) contractions as measured with the dynamometer. The flexion/extension ratios showed that the subjects performed equally well in both directions. The LOS test was significant in medio-lateral direction in favor of the control leg. VM and VL activity was not different, however VM was not in synchrony with VL, it varied from subject to subject. Both, kinetic and kinematic data did not reveal significant difference in the knee angles between the involved and uninvolved knees.
CONCLUSIONS: Dynamometer and force plate analysis were essential in identifying cases idiopathic AKP. Special emphasis should be placed on LOS in medio-lateral directions which seem to be more indicative of the subjects discomfort and self confidence than the movements requiring loading during knee flexions.

T05.P01
CORTICOMOTOR FACILITATION ASSOCIATED WITH IMPLICIT AND EXPLICIT MOTOR IMAGERY IN PATIENTS WITH PARKINSON'S DISEASE

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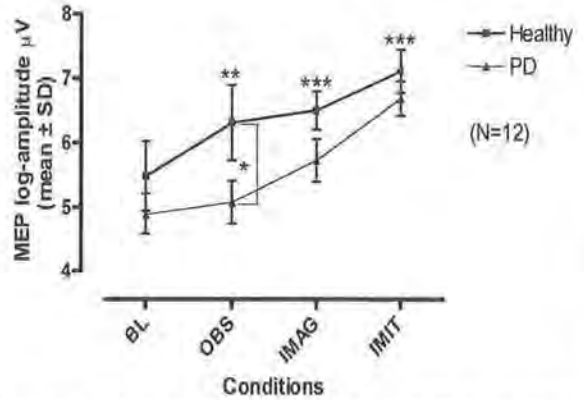
AIMS: Parkinson's disease (PD) is known to affect the ability to generate actions. In the present study, we examined whether this deficit could also affect the ability of patients to engage the motor system when actions are implicitly imagined during observation and also during explicit motor imagery.
METHODS: Twelve subjects (6 medicated PD and 6 age-matched healthy controls, age range 58-75 years) underwent transcranial magnetic stimulation of the left motor cortex while viewing a hand action displayed on a 17" video monitor. The action represented a male subject cutting a piece of material using scissors. Corticomotor excitability was assessed by monitoring changes in motor evoked potentials (MEP) recorded in the *first dorsal interosseus* (FDI) and *abductor digiti minimi* (ADM) muscles. MEPs were monitored under four viewing conditions: 1) close eyes and instructions to relax for 10 s (BL: baseline), 2) observe action (OBS), 3) imagine action (IMAG), and 4) imitate action (IMIT). The four conditions were presented 10 times in a predetermined random sequence. Average MEP amplitude values, after log-transformation, were derived for each condition in each subject. Individual values were then entered into a 4 X 2 (Condition X Status (PD, healthy)) repeated measures ANOVA.
RESULTS: The ANOVA revealed a large and significant effect of "Condition" on MEP amplitude for both the FDI and ADM muscles ($p<.001$). In the FDI, post-test analysis showed that MEPs were significantly larger ($p<0.01$) in the OBS, IMAG and IMIT conditions as compared to BL (see Figure). In the ADM, the facilitation was less important than in the FDI and was significant only for the IMAG and IMIT conditions. A significant "Condition X Status" interaction ($F_{3,8}=3.9$, $p=.05$) was also noted for the FDI. In fact, PD patients exhibited significantly ($p<.05$) lower MEP facilitation than healthy controls in the OBS condition (see Figure). No such difference was found for the two other conditions.
CONCLUSIONS: The present results confirm that the corticomotor system is at work during implicit motor imagery when observing an action, as well as during explicit imagery of the same action. The ability of PD patients to engage the motor system during implicit imagery was less effective than in controls. Such a difference could reflect their impaired capacity to energize the motor system in preparation for action as a result of the dysfunction in the cortico-striatal basal-ganglia loop.



*Comparison of the mean changes in MEP amplitude across viewing condition and between groups test (*p<.05, **p<.01, ***p<.001).*

This work was made possible through support by NSERC (Canada) to F. Tremblay. GL received scholarships from CIHR and Ontario Graduate Studies.

T05.P02
ELECTROMYOGRAPHIC ANALYSIS OF MOUTH'S ORBICULAR MUSCLE IN INDIVIDUALS CLASS II

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AIMS: Bucal respiration is believed to bring serious effects in cranio facial development and occlusion, when there is no correlation among the internal and external forces of bucal musculature. This way, for a precocious diagnosis and the formulation of a suitable tratment plan it is fundamental to know whether the individuals' peribucal musculature has suffered ambiental influences, to the point of altering its physiology. This electromyographic study's purpose was to compare the medial superior region of mouth's orbicular muscle in two groups: G1 (predominantly nasal respiratory pattern) e G2 (predominantly bucal respiratory pattern)
METHODS: 50 brazilian children from 6 to 9 years old were evaluated, 25 boys and 25 girls with Angle's Class II division 1 malocclusion. The EMG activity was captured by an *EMG System do Brasil Ltda* composed of differential double electrode, a bandpass filter at 20 to 1000 Hz, and a subsequent amplification of 50 times with a common mode rejection ratio of 120 dB. The data was sent to a 14-bit A/D converter and sampled at 2000 Hz. A differential double electrode was used, with pre-amplification with 100 times pre-amplification, 25 mm^2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. The electrodes were placed bilaterally over the mouth's orbicular muscle. All applicable recomendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures. Signal handling consisted in full wave rectification, linear envelope through 4th order Butterworth filter, with 5 Hz cut off frequency, normalized in time base and amplitude, this one through average value. EMG signal's intensity variability was calculated through the variability coeficient (VC). The comparison between the EMG signals from the various muscles was made with the t-test, with significance level of 0.05.
RESULT: Variations of around 20% were found among samples during the pronunciation of letters A and F, not found at rest
CONCLUSION: Other new observations to confirm these findings should be performed, specially with older children, to detect the time frame in which occurs a differentiation (the time frame in which, for instance, the bucal habits are installed, and the time frame in which ortodontists or phono must interfere), resulting in labial incompetence. The deep knowledge of muscular dynamics gives the basis to the correct terapy. In this context, electromyography becomes a vast exploration field, with valuable contributions not only to Ortodonty, but also to Physioteraphy and Phonoaudiology.

T05.P03
EFFECTS OF MYORELAXING SPLINTS ON THE MASTICATORY MUSCLES OF INDIVIDUALS WITH TEMPOROMANDIBULAR DYSFUNCTIONS

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AIMS: Temporomandibular dysfunction (TMD) is characterized by a set of symptoms including pain on the temporomandibular joints (TMJs) and masticatory muscles, limitations to mandible movements, and articular sounds. In dentistry, the most frequent

treatment for TMD is using myorelaxing or stabilization splints, which simulate an ideal occlusion and thus favor the condyle-fossa relationship and reduce symptoms.
METHODS: This project involved 10 individuals with TMD signs and symptoms treated with resilient occlusal splints. The subjects were clinically evaluated according to the criteria used by the Occlusion discipline at the Ribeirão Preto School of Dentistry, and the *Research Diagnostic Criteria for Temporomandibular Disorders* (RDC/TMD) was used to determine the presence or absence of TMD. The electromyographic activities of the right and left masseter and temporal muscles were recorded for the clinical conditions: rest, right and left laterality, teeth clenching and protrusion; before (initial), 30 and 60 days after using the resilient occlusal splint. A 12 channel Myosystem I electromyographer (Prosecon Ltda, Uberlândia, MG, Brazil) was used, with simultaneous acquisition, common grounding for all channels, low pass filters of 10 Hz and 5 Hz; 10 GΩ channel entrance impedance in differential mode, 12 bits range of dynamic resolution, an amplitude range of -10V a +10V, and 2KHz sample frequency per channel. The myoelectric signals were captured by differential active electrodes with two contacts measuring 10 x 1 mm and distant 10 mm apart, with an entrance impedance of 10 GΩ and a common mode rejection rate of 130 bB to 60 Hz, made of silver and fixed in a resin capsule measuring 40 x 20 x 5 mm. A 3-cm² stainless-steel reference electrode was also used to reduce the effects of electromagnetic interferences and other acquisition sounds. All data were normalized and statistically analyzed by test-t with the software SPSS (Chicago).
RESULTS: The results revealed that during rest, and using the splint, there was an increase in electromyographic activity for all the assessed muscles. The same was observed for teeth clenching and protrusion. Concerning right and left laterality, the electromyographic means increased during the 30 initial days, and, after 60 days of using the splint, there was a reduction, but not less than the initial values.
CONCLUSIONS: Therefore, we conclude that the increase in activity may be related to the reduction of the initial painful symptoms, thus allowing for a better adequacy and functioning of the stomatognathic system, and, above all, the patients were able to return to their normal activities with an improved quality of life.

T05.P04
EFFECT OF PARKINSON'S DISEASE ON ELETCROMYOGRAM AND MECHANOMYOGRAM DURING SUBMAXIMAL AND MAXIMAL ISOMETRIC CONTRACTION

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AIMS: The purpose of this study was to assess the effect of Parkinson's disease symptoms on electrical (EMG) and mechanomyographical (MMG) activities of the biceps brachii muscle (BB) during submaximal and maximal (MVC) isometric contraction.
METHODS: Six old females (control; CO) and five old females with Parkinson's disease (PD) were tested. They performed three isometric contractions of elbow flexors on a maximal (MVC) and submaximal (20 N load for all) level of force. The EMG and MMG signals were recorded from the short head of the BB using a custom made EMG/MMG probes. The analysed parameters were the amplitude and median frequency of EMG and MMG signals (RMS-EMG, MdF-EMG, RMS-MMG, MdF-MMG, respectively). The mean values of the parameters were calculated from three trials. Then the Univariate Analysis of Variance with stage of disease (assessed by the Hoehn and Yahr scale; H&Y) as a covariate and group as a fixed factor was used for statistical analysis.
RESULTS: The PD group, compared to CO group, was characterized by a smaller MVC (108±20 N and 186±29 N, recpectively) and bigger RMS-MMG values. The results indicate the influence of action tremor and changes in mechanical properties of PD patients' muscle. The assumption is supported by the dependance of the RMS-MMG on the Parkinson's disease stage in maximal and submaximal isometric contraction.
CONCLUSION: It is concluded that the MMG signal gives more information on Parkinson's disease symptoms than recording the EMG. Thus, the mechanomyography apears to be promising method in an evaluation of Parkinson's disease symptoms.

LOAD	GROUP	EMG of BB				MMG of BB			
		RMS [μV]		MdF [Hz]		RMS [mV]		MdF [Hz]	
		X	SD	X	SD	X	SD	X	SD
2 kg	PD	16	5	92	16	18 *	17	15	5
	CO	23	10	93	9	8	2	18	3
MVC	PD	66	27	87	11	45 *	43	16	6
	CO	93	42	90	4	24	3	23	4

* = P≤0.05; PD compared to CO group
X = mean value
SD = standard deviation

P05.P05
EFFECTS OF TEMPOROMANDIBULAR DYSFUNCTION ON THE STOMATOGNATHIC SYSTEM - AN ELECTROMYOGRAPHIC ANALYSIS

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AIMS: With a view to a better understanding of the physiopathology that affects stomatognathic system muscles, the electromyographic analysis of masticatory muscles allows for a verification and quantification of muscle balance, among muscles from both sides of the body (symmetry) and among pairs of muscles, with a possible effect of lateral deviation of the mandible at the upper jaw (torque). In addition, the quantitative analysis of muscle contraction patterns during standardized dynamic activities makes it possible to assess muscular coordination, before and after changing the occlusal surfaces.
METHODS: This study aimed to analyze the masseter and temporal muscles of 10 subjects with temporomandibular dysfunction (TMD) (Group 1) compared to 10 control subjects (Group 2), matched one-by-one per gender, weight, height, and age. The following clinical activities were evaluated: rest, bilateral laterality with contact, protrusion, and teeth clenching. A 12 channel Myosystem I electromyographer (Prosecon Ltda, Uberlândia, MG, Brazil) was used, with simultaneous acquisition, common grounding for all channels, low pass filters of 10 Hz and 5 Hz; GΩ channel entrance impedance in differential mode, 12 bits range of dynamic resolution, an amplitude range of -10V a +10V, and 2KHz sample frequency per channel. The myoelectric signals were captured by differential active electrodes with two contacts measuring 10 x 1 mm and distant 10 mm apart, with an entrance impedance of 10 GΩ and a common mode rejection rate of 130 dB to 60 Hz, made of silver and fixed in a resin capsule measuring 40 x 20 x 5 mm. A 3-cm² stainless-steel reference electrode was also used to reduce the effects of electromagnetic interferences and other acquisition sounds. All data were normalized and statistically analyzed by test -t with the software SPSS (Chicago).
RESULTS: The results revealed that control subjects showed greater electromyographic means during rest and teeth clenching that were significant only for the right masseter ($p<0.05$), whereas subjects with temporomandibular dysfunctions showed greater electromyographic means for right and left laterality and protrusion.
CONCLUSIONS: This evidences a difference in muscle contraction patterns during standardized dynamic activities of the masticatory muscles.

Multichannel EMG and electrode arrays

OPTIMAL MONO- AND BIPOLAR ELECTRODE LOCATIONS IN FACIAL ELECTROMYOGRAPHY DETERMINED BY SINGLE MOTOR UNIT ANALYSIS

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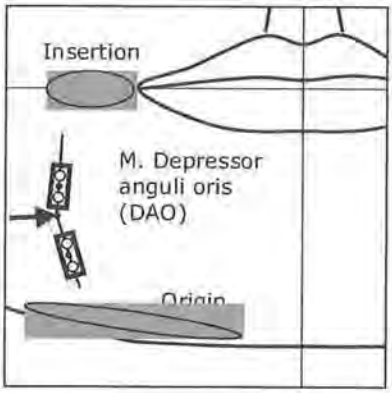
AIMS: Electromyography (EMG) of the complex facial musculature is applied in biomedical and clinical disciplines for functional studies. Electrode placement is mainly based on macro-anatomical knowledge, because relevant quantitative topographical information on anatomic and neurophysiologic parameters of facial motor units (MUs) is lacking. The purpose of this study was to fill this gap of knowledge and to establish objective guidelines for EMG electrode placement in the face.

METHODS: Thirteen healthy subjects were trained to improve motor control on individual facial muscle subcomponents. Thin and flexible electrode grids (120 channels) were used for high-density surface surface EMG (sEMG) recordings during selective contractions of nine facial muscles at different activity levels. MU action potentials (MUAPs) were decomposed from recorded data according to the spatio-temporal amplitude characteristics of detected peaks. Optimal locations of mono- and bipolar electrodes were determined by means of topographical analysis of the MUAPs including determination of endplate positions, muscle fibre orientations and evaluation of amplitude profiles (Figure). Prior to mean value calculation over the subjects, individual results were spatially warped to correct for the different sizes and shapes of individual faces.

RESULTS: Most examined muscles showed a cluster-like endplate distribution with centric or eccentric endplate locations on the muscle. The amplitude profiles showed a large spatial variability within the territories of the MUs and muscles, respectively. Territories of facial MUs belonging to different muscles often do largely overlap resulting in unavoidable cross-talk in EMG recordings in the facial area.

CONCLUSIONS: This study provides basic information about facial MU topography and establishes objective guidelines for placement of conventional (surface or needle, mono- or bipolar) EMG electrodes in the face. Optimal electrode placements should increase the validity of future recordings from this challenging, but not yet well-understood muscle system.



Topographical evaluation of nine single MUs decomposed from sEMG signals recorded during a low-level contraction of the depressor anguli oris muscle (DAO). The small grey dots and thin lines represent the MUs' endplate locations (central dot), main muscle fibre directions and optimal bipolar electrode positions (two positions for bipolar recordings in upper and lower DAO part). The bold black dots and lines indicate the amplitude-weighted mean values of these MUs. Optimal electrode placement in this subject and muscle is indicated for monopolar (arrow) and bipolar electrode montages (two rectangles)

SPATIAL REORGANISATION OF UPPER TRAPEZIUS MUSCLE ACTIVTY IN PRESENCE OF EXPERIMENTAL MUSCLE PAIN

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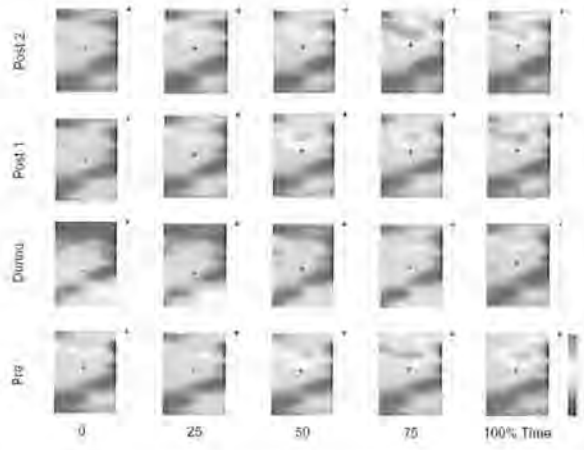
AIMS: The aim of the study was to investigate the effect of excitation of nociceptive muscle afferents on the spatial distribution of upper trapezius muscle activity.

METHODS: Surface electromyographic (EMG) signals were recorded from the upper trapezius muscle of ten healthy volunteers (age, mean ± SD, 23.9 ± 1.9 yr) with a 5×13 grid of electrodes (2-mm diameter, 8-mm inter-electrode distance in both directions) during 90-s static contractions before, during, 15 and 30 min after intramuscular injection of hypertonic (painful) or isotonic (non-painful) saline. From the multi-channel EMG recordings, two-dimensional maps of root mean square and mean power frequency were obtained. The centre of gravity of the root mean square map was used to quantify changes in the spatial distribution of muscle activity.

RESULTS: During sustained contractions, average root mean square increased (from, mean ± SE 73.8 ± 0.6 to 85.7 ± 0.6 μV; $P < 0.001$), average mean frequency decreased (from 92.2 ± 0.2 to 86.1 ± 0.2 Hz; $P < 0.001$) and the centre of gravity moved cranially (shift 4.9 ± 0.3 mm in 90 s; $P < 0.001$). During experimental muscle pain, compared to before injection, the average root mean square decreased (from 82.6 ± 0.5 to 71.8 ± 0.5 μV; $P < 0.001$) and there was a caudal shift of the centre of gravity (4.7 ± 0.4 mm; $P < 0.001$). Fifteen minutes after the painful injection the centre of gravity returned to its original position.

CONCLUSIONS: The results provide evidence of short-term dynamic reorganization of the spatial distribution of muscle activity in response to nociceptive afferent input, probably mediated by space-dependent reflex inhibition of motor unit activity.



Root mean square maps of a subject for 0, 25, 50, 75 and, 100% of contraction time before, during, 15 min and 30 min after intramuscular injection of hypertonic saline. The full dot represents the position of the centre of gravity of each map. Colors are scaled between the minimum and maximum root mean square values (see color bar in the bottom right corner; 0 μV dark blue, 150 μV dark red).

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PRELIMINARY SIMULATION RESULTS OF A METHOD FOR OPTIMIZING SPATIAL FILTERS IN HIGH-RESOLUTION ELECTROMYOGRAM ARRAYS

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AIMS: Decomposition of single motor unit activity in human muscle has typically been accomplished with needle electrodes, which are more spatially selective than conventional surface electrodes and can be situated close to the origin of the electrical activity. However, high resolution surface electrode arrays that can resolve individual action potentials have been demonstrated. These arrays employ spatial filtering to enhance the spatial selectivity of the EMG, limiting the volume of muscle that contributes to the predominant electrical signal. Typically, the normal double differentiating (NDD, or "Laplacian") spatial filter, derived from the field of image processing, is used to reduce the number of superimposed action potentials. In this presentation, we describe a novel optimal EMG spatial filter technique that minimizes the muscle tissue volume whose action potential (AP) firings are prevalent in the resultant spatially filtered signal.
METHODS: Simulations were used to model an AP as a traveling tripole within the muscle, and to calculate the resultant electrical potential induced at an array of monopolar point electrodes positioned at the skin surface. The simulated data were used in conjunction with a map of *desired* spatially filtered output voltages and optimization theory to determine spatial filter weights to achieve the highest spatial selectivity. Two metrics were used to compare spatial selectivity. The first locates the 3 dB drop (from the peak voltage) of the spatially filtered voltage in the skin plane and models this contour as an ellipse. The area of the ellipse is the first metric. The second metric simulates two adjacent APs, one in the region of tissue interest and the other physically offset; the ratio of the peak magnitude from the offset AP with respect to the first is the metric. Smaller values for both metrics imply better spatial selectivity.
RESULTS: The optimal filters were found to be consistently superior to the NDD filter with both selectivity metrics. For example, a 15x15 optimal filter was created for APs at a depth of 7mm, with an interelectrode spacing of 2.5 mm. The center of the array was set as the region of interest. The 3 dB area (first selectivity metric) for the optimal filter was 40% of the NDD filter's area, indicating a noticeable increase in spatial selectivity. For the case of two adjacent APs, the first in the center of the region of selectivity and the second with an offset of 2 mm (second selectivity metric), the optimal filter suppressed the second AP to only 12.1% of the first's peak amplitude, while the NDD filter's attenuation was to 77.9% of the first peak's amplitude. Selectivity was a function of the simulated inter-electrode spacing and the number of electrodes in the array.
CONCLUSIONS: The optimal filters were shown to be superior to the NDD filters. Testing with more realistic simulation models and in human subjects is warranted, based on these initial successful results. The structure of the technique is readily adaptable to more realistic simulators, since the optimal algorithm accepts "black box" simulation data representing the monopolar voltages recorded from an array of electrodes. Thus, more complex models could be used to find a more robust spatial filter for more realistic physiologic conditions.

MUSCLE FIBER ORIENTATION ESTIMATION USING A 2-DIMENSIONAL ELECTRODE ARRAY

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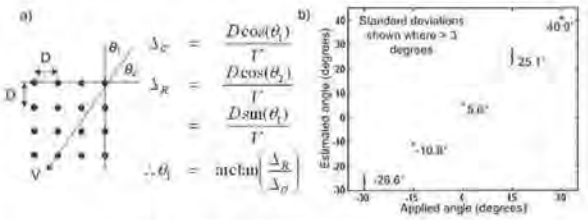
AIMS: The accuracy of muscle fiber conduction velocity (MFCV) measurements is dependent on a variety of factors, including the alignment of recording electrodes along the muscle fibers of interest. Electrode array misalignment can introduce errors of up to 3 m/s in MFCV measurements. Proper alignment of the array along the muscle fibers is cumbersome, and there is no guarantee that this alignment will always be optimal, as the muscle fiber orientation (MFO) may change with changes in joint angle. A 2-dimensional electrode array should contain information regarding the orientation of muscle fibers within its pickup area. Using this angle information, MFCV estimates could be adjusted to account for electrode array misalignment.
METHODS: Given an electrode array as shown in Figure a, and assuming that the propagating action potentials may be modeled as a plane wave, the delays between adjacent electrodes of each row (Δ_R) and each column (Δ_C) may be calculated as shown, where D is the interelectrode distance, and V is the velocity. The offset angle θ_i may then be calculated using the arctangent of the ratio of Δ_R and Δ_C. This estimation procedure was verified in simulation.
For experimental validation, 4x4 electrode grids were applied one at a time to the biceps brachii of one subject at angles of -30, -15, 0, 15 and 30 degrees, with 0 degrees being assumed alignment along the muscle fibers. Ten contractions were performed at each electrode rotation using 40% MVC and a joint angle of 135 degrees. To achieve a 4x4 configuration, myoelectric signal data were recorded from the electrodes in a monopolar configuration, and then combined in software to create bipolar signals to reduce 60 Hz inteference and non-propagating components. Two delays along each row and column between adjacent bipolar pairs were calculated using the shift in the cross-correlation function from zero. These estimates were averaged to obtain a delay estimate for each row and column. There were 16 possible row/column combinations, producing 16 MFO estimates which were then averaged to produce an overall angle estimate for each of the 5 electrode placements.
RESULTS: The angle estimates obtained using the MFO estimation algorithm are shown in Figure b. These estimates compare favourably with the assumed electrode placement angles, especially if we consider that the initial placement at 0 degrees was a visual assumption, and that placing arrays at exact 15 degree increments on a bicep is a difficult task.
CONCLUSIONS: It has been shown that the MFO estimation algorithm performed well for the given subject, however more experimentation is required to show general applicability. Also, in the future, other electrode configurations (double differential, Laplacian, etc.) may be explored to improve the performance of the algorithm in the presence of non-propagating end effects and other noise.



a) An arbitrary 2-dimensional electrode array
b) Experimental results

A COMPARISON OF SURFACE AND INTRAMUSCULAR MYOELECTRIC SIGNAL CLASSIFICATION

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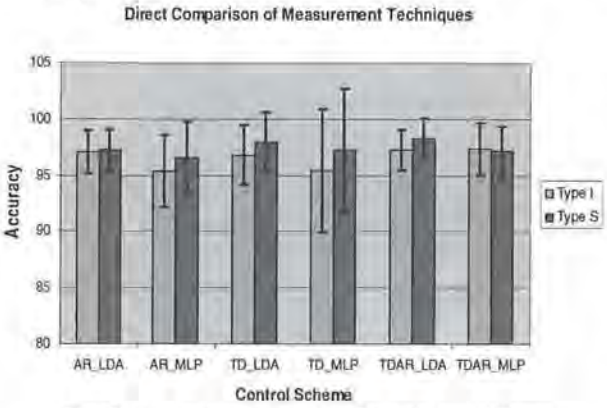
AIMS: The surface myoelectric signal (MES) has been used as an input to controllers for powered prostheses for many years. As a result of recent technological advances, it is reasonable to assume that there will soon be implantable myoelectric sensors which will enable the intramuscular MES to be used as input to these controllers [1]. An intramuscular MES measurement will have less muscular crosstalk allowing for more independent

control sites. However, it remains unclear if this benefit outweighs the loss of the global information contained in the surface MES.
METHODS: This study compares the performance of six pattern recognition based myoelectric controllers which use information extracted from surface MES to the same controllers which use information extracted from intramuscular MES. The surface and intramuscular MES were collected simultaneously for ten, medium force isometric contractions of five seconds duration, corresponding to the motions: wrist flexion\extension, wrist abduction\adduction, forearm pronation\supination, key grip, chuck grip, open hand, and gently move fingers. A 16 electrode array [2] was wrapped around the upper forearm to measure the surface MES; no specific placement strategy was necessary as its global pickup provides complete spatial coverage of the circumference of the limb. For intramuscular measurements, 44 gauge fine-wire electrodes were inserted into six control sites in the forearm: pronator/supinator teres, flexor/extensor carpi ulnaris, flexor digitorum sublimas and extensor digitorum communis. The data set for each subject consisted of two trials. Each trial consisted of two repetitions of the ten motions.
The data sets were processed with a variety of feature sets and classifiers. Time domain (TD), autoregressive (AR), and concatenated time-domain and autoregressive (TDAR) feature sets were classified using linear discriminate analysis (LDA) and a multi-layer perceptron artificial neural network (ANN) classifier.
RESULTS: A comparison of the performance of each of the feature set/classifier combinations resulting from the two different measurement techniques is presented in the Figure.
CONCLUSIONS: These results suggest that it is possible to achieve high classification accuracies using information extracted from either surface or intramuscular MES. There there is no clear benefit in using intramuscular MES in terms of classification accuracy.



Classification accuracies resulting from the two different measurement techniques. Type I is for intramuscular MES and Type S is for surface MES

[1] R. F. Weir, P. R. Troyk, G. DeMichele, and T. Kuiken, "Implantable Myoelectric Sensors (IMES) for Upper-Extremity Prosthesis Control - Preliminary Work," Proceedings of the 25th Annual International Conference of the IEEE EMBS, Cancun, Mexico, pp. 1562-1565, Sep. 2003.
[2] Prima Biomedical and Sport, Via Fermi, 23/A - 31010 Mareno di Piave (TV) Italy

DISTINCTION BETWEEN NECK-SHOULDER PAIN CASES AND HEALTHY CONTROLS WITH COMBINED MULTICHANNEL EMG PARAMETERS

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AIMS: A serious problem encountered with neck-shoulder pain is the lack of objective measures for diagnostic use. Although several studies showed differences between neck-shoulder pain cases and controls, in general the differences are rather small compared to the inter-subject variability. This study investigated whether multiple surface electromyography (EMG) parameters, combined in a logistic regression model, are able to distinguish between cases with neck-shoulder pain and healthy controls.
METHODS: Fourteen controls and thirteen cases performed five tasks: a unilateral dynamic hand task, typing task, editing task, mouse task and stress task. EMG of the trapezius muscle was measured using multi-channel electrode arrays. Initial value and slope of global EMG parameters (RMS and RMS_{SLOPE}) and median power frequency (FMED and $FMED_{SLOPE}$), the number of motor unit action potentials per second (MUAP Rate) and MUAP shape properties (root-mean-square value, and mean power frequency, $FMEAN_{MUAP}$) were calculated.
Subjects were randomly divided into two data sets. The first data set (ten controls and nine cases) was used to develop a logistic regression model for each task. The performance of these models was evaluated with the jackknife method. Further evaluation was performed by applying the best model to the second data set (four cases and four controls).
RESULTS: For the typing task no model could be generated. The mouse task resulted in the most discriminative model. Jackknife evaluation resulted in correct classification of 89% in cases and 90% in controls. Application of the model to the second data set resulted in correct classification of three out of four cases and three out of four controls. Standard deviation (SD) of $FMEAN_{MUAP}$ (lower in cases) and SD of MUAP Rate across time (higher in cases) were the most discriminating parameters.
CONCLUSIONS: The mouse task results in the best model, probably because it is a rather standardized task requiring low force levels at which, according to the Cinderella hypothesis, the best distinction can be expected. The higher intra-subject variability in MUAP Rate in cases may indicate that their activation pattern during a task is more variable. The lower SD of $FMEAN_{MUAP}$ in cases may indicate a more homogeneous motor unit pool. This pilot study shows that a combination of multiple surface EMG parameters might be capable of distinguishing cases with neck-shoulder pain from controls. This is encouraging for development of an objective EMG based test to discriminate cases with neck-shoulder pain from healthy controls.

Task	Parameters included in the model	-2 log likelihood	Specificity	Sensitivity
Dots	FMED, $FMEAN_{MUAP}$_SD	7.01	90.0	88.9
Editing	$FMED_{SLOPE}$	19.3	90.0	66.7
Mouse	$FMEAN_{MUAP}$_SD, MR_SD, RMS_{SLOPE}	0.00	100	100
Stress	MR_SD	14.1	71.4	75.0

Models created from the first data set for each task. The performance is shown in terms of sensitivity (the percentage of correctly classified cases) and specificity (the percentage of correctly classified controls). The -2 log likelihood value indicates how well the model fits the data: a low value corresponds to a good fit

NON-INVASIVE EVALUATION OF UTERUS ACTIVITY DURING LABOR USING A DYNAMIC MAPPING SYSTEM

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AIMS: The objective of this work is to characterize the uterus contractions during labor, using an array of several surface electrodes distributed over the abdominal wall. The aim is to carry out a dynamic mapping of the emg activity, in order to assure an early diagnosis of a preterm delivery or the need of a possible surgical intervention, as well as to determine the proximity of the delivery, with the purpose of avoiding

unnecessary long hours of pain in the mother and fetal suffering, and to minimize the complications of health as much in the mother as in the fetus.

METHODS: We use an array of twelve surface electrodes to monitor the mioelectrical signals produced by the uterus during labor of 10 women. The dynamic mapping system was able to carry out a systematic chronological analysis of the EMG activity on different electrodes and to explore the beginning of the excitement and to provide information with regard to the pattern of intensity, duration, frequency, propagation and coordination of the uterine activity.

RESULTS: Preliminary results show that the mapping system seems to be able to differentiate between a normal Triple Descending Gradient pattern and an abnormal Inverse Gradient which are generated by opposite patterns of gradients. The former producing an efficient dilatation of the cervix and the expulsion of the fetus, and the last closing the cervix preventing the expulsion of the fetus.

CONCLUSIONS: A novel approach for the evaluation of the ability of a dynamic mapping system based on a non-invasive detection of EMG signals is presented. This approach seems to be promissory for the characterization of contractions during labor.

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T06.P01
EXTRACTION OF MOTOR UNIT ACTION POTENTIAL TRAINS FROM MULTI-CHANNEL ELECTROMYOGRAPHIC SIGNALS BASED ON STATISTICAL ANALYSES

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AIMS: The purpose of this study is to measure the separability of the combination between expansion matching filter and independent component analysis (ICA) as a preprocessing procedure for EMG signal decomposition. Nakamura et al. (1) reported that the application of ICA to the EMG signals is useful as a preprocessing procedure for EMG signal decomposition. However, only the application can hardly classify MUAP trains from EMG signals because the application hardly separate all MUAP trains into each independent component. Especially, interference between MUAPs makes it difficult to classify MUAP trains. Therefore, we tried to apply expansion matching filter as a compensator of ICA for classification of MUAP trains. For evaluation of the usefulness of this combination, the separability of the combination was measured as compared with kurtosis values of EMG signals or components.
METHODS: 8-channel bipolar surface EMG signals of tibialis anterior muscle were recorded with surface electrodes whose channels are almost vertically arranged to the running direction of muscle fibers. The subjects contracted isometric dorsi-flexion 10%MVC during the recordings.
Firstly, second order digital filtering, which passes 10 to 500 Hz signals significantly, was applied to the EMG signals. Then, by application of expansion matching filter to the filtered EMG signals, we obtained their expansion coefficients. Expansion coefficients indicate relatively high amplitude spikes at the points where the waveforms between signals and a template are similar with each other. For the practical application of expansion matching filter, as the template, we extracted a candidate MUAP waveform from the EMG signals. ICA was applied to the expansion coefficients. ICA is a statistical signal processing method which estimates statistically independent components from spontaneously recorded multi-channel signals. ICA is often used to separate multi-channel signals into the source signals which satisfy statistical independent severally. By expansion matching filter, only single or a few MUAP train(s) would be remained on the expansion coefficient.
Independent components were estimated by ICA from three subjects' EMG signals after expansion matching filter was applied. Then, we compare the separability of EMG signals, expansion coefficients and independent components. Kurtosis of their components' amplitude distributions was used for the evaluation of separability because, if distribution of a component's amplitude has high kurtosis, it is indicated that the component has a single or a few MUAP train(s).
RESULTS: The application of expansion matching filter made MUAP waveforms other than a single MUAP train be eliminated from the EMG signals. Then, it was found that, by ICA, the single MUAP train was projected into a single or a few component(s). In all three subjects, the number of higher kurtosis values (>10) of independent components becomes more than the EMG signals and expansion coefficients. Therefore, kurtosis values of components may enable us to evaluate separatability of the combination between expansion matching filter and ICA.
CONCLUSIONS: In conclusion, our results indicate that the combination between expansion matching filter and ICA make the possibility become increased to classify MUAP trains owing to reduction of the interference between MUAP waveforms.

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T06.P02
MAPPING OF THE JAW-STRETCH REFLEX EMG ACTIVITY IN THE HUMAN MASSETER

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AIM: The aim of the study was to compare the spatial distribution of EMG activity over the masseter muscle, during voluntary contractions and stretch reflexes.
METHODS: 14 healthy, male subjects (age, mean±SD, 24.6±2.1 yr) free of symptoms of temporomandibular disorders participated in the study. The jaw-stretch reflex (1-mm displacement, 10-ms ramp time) was evoked with a custom-made muscle stretcher (Aalborg University, Denmark). Bipolar surface EMG electrodes were placed over the left masseter and a 5 6 electrode grid (8-mm interelectrode distance) was placed parallel to the fibers of the right masseter. The activity of the left masseter was used for feedback to trigger the jaw stretch, which was evoked when the background EMG activity was stable at 15% (±1.5%) of the maximal voluntary contraction (MVC) for 400 ms. The analysis was done in a bipolar mode. The peak-to-peak amplitude (RPP) was computed for each channel of the grid from the raw EMG signal. The average over 20 reflex sweeps was used for the analysis of the data. Moreover, the average rectified value of each of the EMG signals was computed in the 100-ms interval preceding the reflex (pre-EMG). Normalized peak-to-peak amplitude (NPP) of the reflex was obtained as the ratio between RPP and the pre-EMG. The spatial center of EMG activity (barycenter-BC), relative variability with electrode location, and entropy of the EMG maps were used as global indices for the description of the spatial distribution of the EMG activity. The relative variability and the entropy indicate the degree of heterogeneity of the map. Data (mean±SD) were analyzed with paired Student t-tests. Cross-correlation was also used to compare the RPP and the pre-EMG maps.
RESULTS: There was a large variation among subjects in the spatial cross-correlation coefficient between the RPP and the pre-EMG maps (0.64±0.23). The BC of the RPP map (x-coordinate: 3.19±0.3 mm; y-coordinate: 2.9±0.19 mm) and of the pre-EMG map (x-coordinate: 3.09±0.16 mm; y-coordinate: 2.87± 0.14 mm) were not significantly different. For the RPP map, the relative variability was larger, while the entropy was smaller (231.12±52.42 and 3.9±0.2, respectively) comparing with the pre-EMG map (179.99±33.91 and 4.09±0.19, respectively) ($P< 0.05$). In addition, for the NPP map, the relative variability significantly decreased while entropy significantly increased (225.23±46.67 and 3.93±0.17) with respect to the RPP map (139.50±29.46 and 4.29±0.14) ($P<0.001$).
CONCLUSION: The spatial distribution of the raw peak-to-peak amplitude of the jaw-stretch reflex was moderately correlated with the spatial distribution of the pre-stimulus EMG activity. Despite the moderate correlation, normalization, usually performed in classic reflex studies, significantly decreased the heterogeneity of activation.

Grants: Marie-Curie Fellowship of the European Community program "Marie Curie Training Sites" (HPMT-CT-2000-00092) and the Danish Technical Research Council (project "Centre for Neuroengineering (CEN)", contract n° 26-04-0100).

T06.P03
BEHAVIOUR OF MOTOR UNIT ACTION POTENTIAL RATE, ESTIMATED FROM SURFACE EMG, AS MEASURE FOR MOTOR CONTROL

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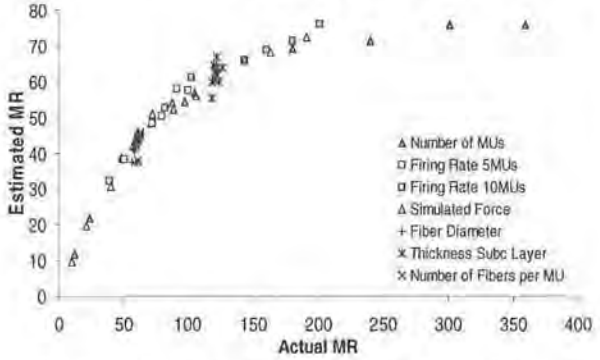
AIMS: Commonly used surface electromyography (SEMG) parameters to investigate muscle activity (e.g. RMS) are influenced by both motor control aspects and properties of the muscle. To assess motor control separately, the number of motor unit action potentials (MUAPs) per second, or MUAP Rate (MR) could be useful. The objective of this study was to explore the behaviour of estimated MR (eMR) from multichannel EMG recordings.
METHODS: Simulations were used to investigate the influence of the following parameters on the relationship between actual MR (aMR) and eMR and on RMS:

Central motor control parameters:
Number of active MUs
Firing rate
'Force' (Nr of MUs and Firing rate combined)

Peripheral parameters:
Number of fibers per MU
Fiber diameter
Thickness subcutaneous layer

RESULTS: The relation between eMR and aMR was very similar for all simulated conditions. In all simulations, eMR was lower than actual MR, largely due to superimposed MUAPs that were not recognized as such. The percentage of detected MUAPs decreased with the number of MUAPs present in the signal. Furthermore, eMR showed high correlations with all central motor control parameters (r^2>0.95), whereas peripheral parameters did not affect eMR, in contrast to RMS.
CONCLUSIONS: The strong relationship between eMR and both number of active MUs and firing rate indicate that eMR clearly reflects these two motor control parameters while it is not affected by peripheral parameters. Although the true number of MUAPs in the signal cannot be accurately extracted with the present method, eMR seems to be a useful tool for assessing motor control, especially at low contraction levels.



Relation between estimated MR and actual MR in different conditions.

T06.P04
ANALYSIS OF FOREARM MUSCLES DURING GRIPPING EXERCISE BY MEANS OF LINEAR ELECTRODE ARRAYS AT DIFFERENT LEVELS OF EFFORT

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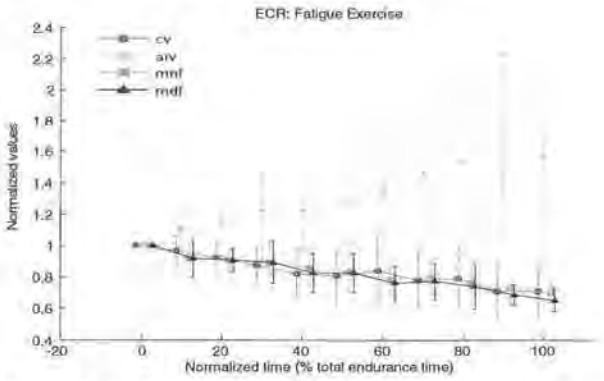
AIMS: Gripping work is related to the development of musculoskeletal disorders and the role of forearm muscles during this kind of contraction is not clear enough. The objectives of this work were 1) to show that surface linear electrode arrays are useful tools for the assessment of forearm muscles, 2) to evaluate EMG amplitude on forearm extensors and flexor muscles at different percentage of the maximal voluntary contraction level (MVC) and 3) to analyze myoelectric manifestation of fatigue during a sustained hand-grip.
METHODS: Eleven healthy male volunteers (age, mean±SD: 30.85±4.50 years) performed voluntary isometric grip contractions at 20%, 50% and 80% MVC in a randomized order. Force feedback was provided by means of a hydraulic hand grip dynamometer. Moreover, a fatiguing contraction was performed at the end of the experiment maintaining a 50% MVC level up to exhaustion. Four forearm muscles were studied: Extensor Carpi Radialis (ECR), Extensor Digitorum Communis (EDC), Extensor Carpi Ulnaris (ECU) and Flexor Palmaris Longus (FPL). Surface EMG signals were recorded from each muscle by means of a linear adhesive array of eight Ag-AgCl electrodes (5 mm inter-electrode distance). Average rectified value (ARV), muscle fiber conduction velocity (CV) and spectral parameters such as mean and median frequency of EMG spectrum (MNF, MDF, respectively) were evaluated and used as indices of fatigue.
All parameters were computed on triplets of EMG signals (series of three consecutive single differentials signals) and cross correlation coefficient (ρ) was used as a quality measure of the estimates.
RESULTS: Linear electrode array technique allow to extract good quality signals from all these muscles overall the subjects: triplets with ρ>0.5 and CV within physiological range (2 m/s< CV<8 m/s) were selected for EMG parameter estimation. Increment of EMG amplitude with effort level in FPL was higher than in DC and ECU ($p<0.003$).
The evolution of the EMG parameters, normalized with respect to their initial value was calculated in order to obtain fatigue plots. Myoelectric fatigue as observed in all muscles as indicated by the decrement of CV and spectral parameters decrement in CR $p<0.001$, in EDC $p<0.02$, in ECU $p<0.02$ and in FPL $p<0.007$). Decrement of CV was higher in ECR than in EDC ($p<0.03$) and also higher in FPL than in EDC ($p<0.02$)
CONCLUSIONS: Surface linear electrode arrays showed to be useful in the assessment of the EMG activity and myoelectric fatigue of forearm muscles. Reliable parameters and good estimates of CV can be obtained. Although the main action of extensor muscles is not the hand grip, they are highly active especially at 20% and 50% MVC. Besides, myoelectric fatigue was observed in all the muscles during a sustained contraction. Finally, the contribution of each forearm muscle to the generation of force in a gripping work depends on the effort level.



Fatigue Plot on ECR: Decrement of CV and spectral parameters due to manifestation of myoelectric fatigue

T06.P05
EVIDENCE OF POTENTIAL AVERAGING OVER THE FINITE SURFACE OF A BIOELECTRIC ELECTRODE USING HIGH-DENSITY EMG

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AIMS: Bioelectric electrodes are widely used within various fields to record bioelectric signals. It is commonly acknowledged that the amplitude of the measured potential varies with the electrode surface area. On the basis of a theoretical model, we hypothesized that, when assuming that the impedance per area unit under the electrode is equally distributed, the potential of a single large electrode equals the average potential of a large number of small electrodes covering the same muscle area.
METHODS: To test this hypothesis, we recorded supra-maximal compound muscle action potentials (CMAPs) in two subjects from the thenar muscle. Signals were recorded using either a high-density electrode grid (consisting of 8x15 electrodes of 2 mm in diameter with an inter-electrode distance of 4 mm) or different sizes of self adhesive single large electrodes which were cut to match with predefined electrode grid areas (1x3 cm, 1.8x1.8 cm, 2.2x2.2 cm, 2.6x3.4 cm). First, the high-density electrode grid was placed on the thenar muscle. The position of the grid's geometry was marked using small holes in between the detection surfaces. A CMAP was obtained by supra-maximally stimulating the median nerve. The electrode grid was then removed and a single large electrode was subsequently positioned on multiple selected grid areas for a repeated CMAP recording. The potentials recorded by the single large electrodes were compared with simulated large electrode potentials by calculating the average of those grid electrodes covering the corresponding muscle area.

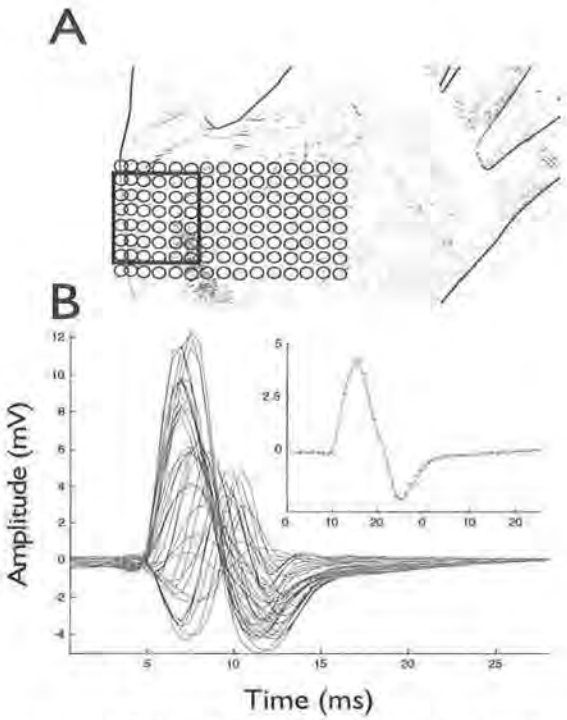

Figure 1: A) 120 electrode contacts on the thenar muscle with a rectangle indicating the position of the single large electrode, B) Individual potentials for each electrode within the rectangle, Inset) simulated large electrode (+) and single large electrode CMAP (line); note the difference in scale.

The relative residual variance (RV) was calculated per stimulus as a measure of the difference between the real and simulated large electrode potentials.
RESULTS: In most cases the computed CMAP of the simulated large electrode matched almost perfectly with the measured CMAP. The mean RV was 3.2% and 1.3% for the first and second subject, respectively. The amplitude variability of the small grid electrodes was relatively high; in some cases, the average CMAP was more than 50% lower than the maximum of the single grid electrode potentials (Fig. 1B).
CONCLUSIONS: The results show sufficient agreement between simulated and large electrode potentials. The small differences may be related to inaccuracy of electrode size and electrode placement. The data confirms our model that a single large electrode corresponds to the average of the underlying bioelectric potentials. Moreover, the results also falsify the opinion that the placement of a large electrode could partly short-cut the volume conductor.

Motor control

SYMPATHETIC MODULATION OF MUSCLE FUNCTION: OVERVIEW AND UPDATE

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The activity of the sympathetic nervous system (SNS) is generally increased during exercise and in any context of psychological or psychosocial stress. It is appropriate to consider the interactions between the SNS and musculoskeletal function, for the following reasons: i) Besides its well-known action on muscle blood flow, the SNS affects muscle function in different ways: modifies the contractility of the muscle fiber, affects the proprioceptive information arising from the muscle spindle receptors and, under certain conditions, can also affect peripheral mechanisms involved in pain perception; ii) the activity of the SNS itself is in turn affected by afferent signals from the muscle, related in particular to muscle fatigue and pain. Such somato-vegetative interaction has gained renewed interest in the field of chronic muscle pain syndromes, whose onset and maintainance appears to be associated with stress condition of different types.

The effect of the increase in sympathetic activity on the musculoskeletal function was studied mainly on anaestetized animal (rat, cat, rabbit) models, as well as on isolated skeletal muscles. Sympathetic activity affects muscle contractility typically producing a potentiation (of both amplitude and duration) of twitch force in type II and a decrease in type I muscle fibers (Bowman 1981; Grassi et al 1996). As for the effects on proprioception, an exhaustive study was performed on rabbit jaw muscles, using three experimental protocols, i.e., by measuring the effect of sympathetic stimulation (at frequencies within the physiological range) on spindle afferent discharge, on the stretch reflexes evoked in the same muscles (Grassi et al 1993), and on rhythmic masticatory cycles elicited by appropriate stimulation of the cerebral cortex (Roatta et al 2005). These experiments show that CSN stimulation produces clear reduction in all tested reflexes, alteration of the masticatory movements and impaired masticatory adjustment to external perturbations. All the above effects were attibuted to the sympathetically-induced depression in the stretch sensitivity of spindle receptors that was observed in both Ia and II muscle spindle afferents, in the relevant muscles (Roatta et al 2002).

At variance with rather consistent and marked effects resulting from animal experiments, the recent attempts to detect similar effects in humans do not yet provide homogeneous results. The concept is often put forward that the decrease in proprioception may results from supra-physiological sympathetic stimulation frequencies and be possibly secondary to blood perfusion changes, rather than to a non-vascular sympathetic action on intrafusal muscles. However three recent observations contradict such a concept: 1) indirect estimates of physiological sympathetic activation in awake animals indicate that sympathetic fibers may fire well above the frequencies that are generally presumed to be the upper physiological limit (Roatta et al, unpubl.); 2) morphological studies have identified high density of non-vascular adrenergic receptors on intrafusal fibres of rabbit jaw muscles (Bombardi et al, in press); 3) NPY co-transmitter of adrenaline is present in intrafusal muscle fibres of human lumbrical muscles (L-E Thornell, personal communication).

CONCLUSIONS: the sympathetic nervous system was shown to be potentially able to affect the motor function, from simple reflexes to coordinated movements. Although the extent of effectiveness in humans remains to be established, a stress-related impairement of proprioception and motor control should be considered as a possible mechanism behind chronic muscle pain syndromes. Such impairemant may in fact call for alternative sub-optimal compensatory motor strategies, like recruitment of accessory muscles and development of co-contractions. Since muscle pain and fatigue are known to reflexly activate the sympathetic system, a number of possible feedback loops may be envisaged to develop and maintain a pathological muscle state. Studies on human subjects are needed to adequately prove or disprove the above hypotesis.

FACILITATION OF STRETCH REFLEX IN HUMAN SOLEUS MUSCLE DURING PASSIVE STANDING

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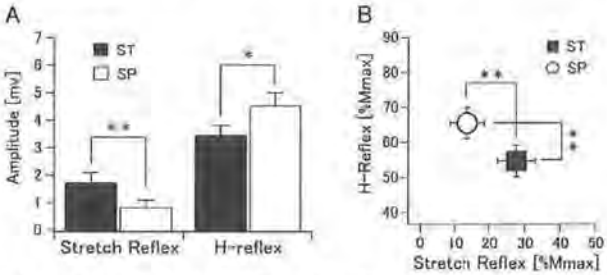
AIMS: It is well recognized that the amplitude of the soleus H-reflex is suppressed in standing as compared to those in sitting or supine postures. The aim of our study was to ascertain whether or not the excitability modulation of the stretch reflex shows similar manner to those of H-reflex.

METHODS: A custom-made device to elicit stretch reflex actions in the soleus muscle was mounted on the lower leg portion of a gait orthosis. With the use of this orthosis, a subject can stand passively without background EMG activity in the soleus muscle. Eight healthy subjects (29.6±5.4 yr) were placed in the orthosis, and the stretch and H-reflex responses were elicited when the subject kept standing (ST) and supine (SP) postures. Peak-to-peak amplitudes of both stretch and H-reflex EMG activity were evaluated, and all reflex responses were normalized to the maximum motor response (M max).

RESULTS: The result clearly showed suppression of the H-reflex amplitude during the ST compared with SP condition (ST vs. SP: 3.5±0.3 vs. 4.6±0.5 mv). This result was in good agreement with the previous reports. On the other hand, amplitude modulation of the stretch reflex showed an opposite manner to those in H-reflex (ST vs. SP: 1.8±0.4 vs. 0.9±0.3 mv). All subjects showed significantly larger stretch reflex responses while standing.

CONCLUSIONS: The present results indicated that the passive standing posture itself has different effects on the excitabilities of both reflex pathways. The posture-dependent changes in muscle spindles or the presynaptic inhibition onto spinal motoneurons may account those differences.



*A: comparison of the stretch and H-reflex responses between ST and SP conditions. B: relative changes of both reflex amplitude in accordance with the postural conditions. error bars indicate sem. (**p<0.01 , *p<0.05)*

TASK-DEPENDENT REFLEX CONTRIBUTIONS TO MULTIJOINT COORDINATION

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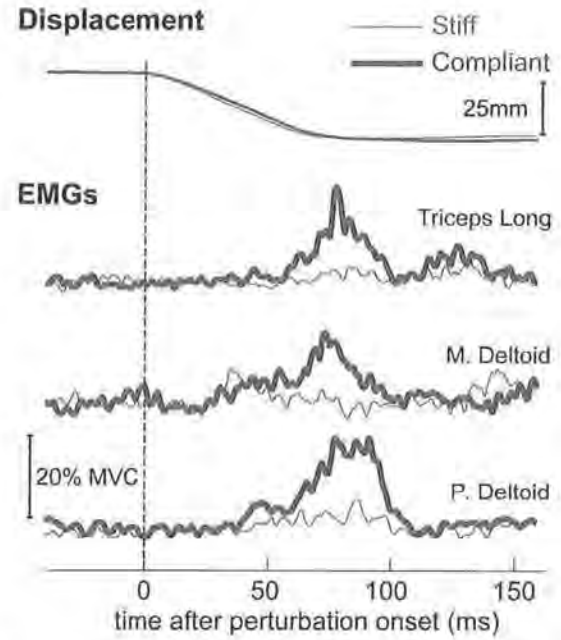
AIMS: The human motor system regulates arm mechanics to produce stable postures during interactions with a variety of environmental loads. These mechanics are regulated by controlling the actions of multiple muscles within the arm using both spinal and supraspinal pathways. Single joint studies have demonstrated that stretch reflex contributions to mechanics vary with task and can increase to compensate for environmental loads with low stability. This suggests that reflex modulation is a fundamental component of motor function, but the extent of this modulation has yet to be investigated during multijoint tasks. The purpose of this study is to examine how multijoint stretch reflexes vary with

changes in environmental stiffness. Our hypothesis is that reflexes increase to compensate for decreased environmental stiffness and that these increases are appropriate for maintaining whole limb stability.

METHODS: Reflexes were elicited in four subjects by applying ramp-and-hold displacements to the endpoint of the arm. These were applied along three orthogonal axes using a rigid 3D robotic manipulator [HapticMaster; FCS Control Systems, The Netherlands]. To investigate the influence of environmental stiffness on the elicited reflexes, the manipulator was used to simulate stiff (10 kN/m) and compliant (10 N/m) environments. For reference, the stiffness of the arm in these experiments typically ranges from 100-500 N/m. During each experiment, subjects were instructed to exert a constant force against the manipulator by pulling towards the body or pushing away from the body at 0%, 5% or 10% of maximum voluntary contraction (MVC). Reflexes were quantified as the change in average rectified EMG between 50-100ms (highlighted area in Figure) following perturbation onset. Results were averaged across 20-25 trials for each condition.

RESULTS: For all subjects, reflex responses increased significantly during interactions with the compliant environment. The Figure shows typical changes observed in a single subject when voluntarily pushing outward. Across all tasks studied, changes in load stiffness had the largest effect on the reflexes elicited in shoulder muscles. Increased co-contraction also was observed when subjects interacted with compliant environments, but the observed changes in reflex EMG were significant, even when changes in background activity within a given muscle were considered.

CONCLUSIONS: The stretch reflex response to perturbations of multijoint posture is modulated in a task-dependent manner. Our results demonstrate increased responses to muscle stretch, even at matched levels of background activity within a given muscle. These findings may be due to increased homonymous reflex gain or increased contributions from heteronymous pathways and are consistent with reflex pathways that are able to increase limb stability to compensate for less stable environments.



Reflex responses to whole limb perturbations applied at the hand and directed horizontally toward the midline. These muscles exhibited significantly different reflexes for matched perturbations and background activity

SPINAL REFLEXES OPTIMALLY ADAPT TO UNSTABLE ENVIRONMENTS

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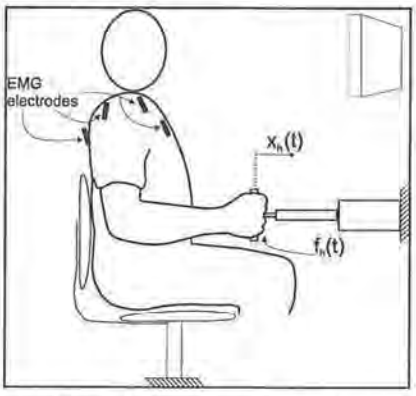
AIMS: Continuous random force disturbances have proven to be useful to quantify spinal reflexes and such to assess the functionality of reflexes. In this study it is investigated how humans adapt the strength of the reflexive feedback when interacting with unstable environments (negative stiffness or damping). The effectiveness of the quantified reflexive feedback gains is evaluated by comparing the results with model optimisations.

METHODS: Subjects were instructed to hold a handle and to "minimize the deviations", while continuous random force disturbances were applied via a handle for 30 s, see Figure. The magnitude of the force disturbance was adjusted such that the position deviations of the handle were within 10 mm amplitude, facilitation linearization. During a trial the position of (x) and the force at (f_h) the handle were recorded along the surface EMG of four relevant shoulder muscles (m. pectoralis major; m. deltoideus anterior; m. deltoideus posterior; m. latissimus dorsi). The EMG signals of the four muscles were combined to get one (lumped) muscle activation signal (a), using the individual EMG-to-force ratios. The data were transformed to frequency domain and the frequency response functions (FRFs) for the mechanical admittance (f_h/x) and the reflexive impedance (a/x) were calculated. Parameters for muscle visco-elasticity, reflexive feedback gains and neural time-delay were quantified by fitting a model onto both FRFs simultaneously. To provoke different reflexive feedback gains the damping and stiffness applied by the manipulator were varied over the trials. The quantified reflex gains were compared with model optimisations.

RESULTS: 1. Reflexive feedback increases with negative external stiffness and decreases with negative external damping.
2. The modulation of the reflexive feedback strength is comparable with the model optimisations, indicating that the experimentally quantified values are optimal to suppress the force disturbances.

CONCLUSIONS: Humans are able to modulate the strength of the reflexive feedback and these modulations are optimal to minimize the deviations, even when applying unstable environments. A model analysis reveals that negative stiffness and positive damping increase stability margins, where reflexive feedback decreases stability margins. The results of this study suggest that humans modulate the reflexive feedback optimally to maximize stiffness while maintaining sufficient stability.



Experimental setup. Subjects could move the handle for- and backwards resulting ante-/retroflexion of the shoulder

HETERONYMOUS REFLEX CONTRIBUTIONS TO MUSCLE ACTIVITY IN THE UPPER LIMB

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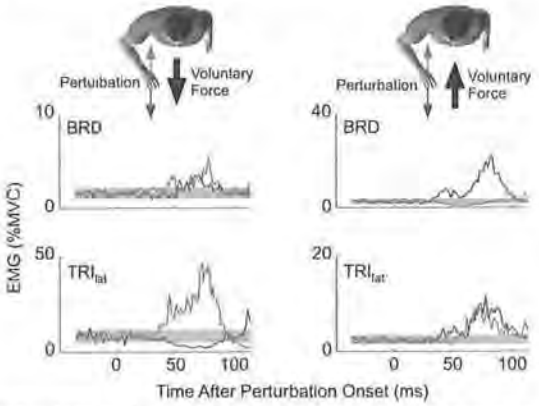
AIMS: Deafferentation and sensory neuropathies that impair proprioception grossly disrupt interjoint coordination. Abnormal coordination also is a hallmark of central nervous system disorders, such as stroke and spinal cord injury, and there is mounting evidence that stretch sensitive reflexes contribute to that discoordination. Despite this significance, few studies have addressed the role of stretch reflexes in the unimpaired control of multijoint movement and posture. The purpose of this study is to examine the contributions of homonymous and heteronymous stretch reflex pathways in coordinating the response to whole limb perturbations. Our hypothesis is that heteronymous reflex linkages are necessary to account for the patterns of muscle activation that emerge in response postural disturbances of the human arm.
METHODS: Reflex responses were elicited in four subjects by applying ramp-and-hold displacement perturbations to the endpoint of the arm. These were applied along three orthogonal axes using a rigid 3D robotic manipulator [HapticMaster; FCS Control Systems, The Netherlands]. During the experiment, subjects were instructed to exert constant forces against the manipulator by pulling in towards the body or pushing away from the body. Force levels of 0%, 5% and 10% of maximum voluntary contraction (MVC) were investigated. Muscle length changes in response to the perturbations were estimated using a 3D biomechanical model of the upper limb [Anybody technology, Denmark]; Monte Carlo analyses were used to assess prediction accuracies. Surface electromyograms (EMGs) were measured from 8 muscles in the perturbed arm. Excitatory EMG responses during muscle shortening and inhibitory responses during lengthening were considered to be evidence of significant heteronymous contributions to the observed reflex responses.
RESULTS: Long and short latency responses were observed in all muscles; long latency responses had the largest magnitude. Long-latency heteronymous responses were observed in all subjects (Figure). Most corresponded to increased muscle activation during shortening, and were observed most consistently in the brachioradialus (BRD), the calvicular pectoralis ($PECT_{clav}$) and the lateral triceps (TRI_{lat}). However, the nature of these responses varied across muscles. Heteronymous responses in the BRD were observed across the widest range of conditions, but their magnitude remained small. The largest responses were observed in the $PECT_{clav}$, but in a smaller subset of the conditions tested. Specifically, the responses in this proximal muscle appeared to depend on changes in both elbow and shoulder angle. TRI_{lat} responses were between these extremes.



Reflex EMG in BRD and TRI_{lat} for two perturbations that caused opposite changes in these muscle lengths. Each muscle had excitatory responses during lengthening and shortening when the antagonistic muscle was active, suggestive of heteronymous activation

CONCLUSIONS: There is a coordinated reflex response in the muscles of the upper limb following perturbations of whole limb posture. Our results suggest that this coordination is due at least in part to heteronymous reflex connections throughout the limb. The specificity and magnitude of the responses in the proximal muscles is consistent with these muscles receiving afferent inputs from distal musculature.

UPPER TRAPEZIUS MUSCLE PAIN RESULTS IN REORGANIZATION OF COORDINATION AMONG TRAPEZIUS MUSCLE SUBDIVISIONS DURING DYNAMIC MOVEMENT OF THE UPPER LIMB

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AIMS: The aim of this study was to examine the effect of experimental upper trapezius muscle pain on the relative activation of trapezius muscle subdivisions during dynamic movement of the upper limb.
METHODS: Multichannel surface EMG signals (8 contact electrodes, inter-electrode distance 5mm), were detected from nine healthy subjects (4 female, age: 27.2 ± 4.4 yr) from the upper, middle and lower divisions of trapezius during a repetitive shoulder flexion task to the beat of a metronome set at 88 beats/min for 2.5-min. Measurements were performed before and after injection of 0.5 ml hypertonic (pain condition) and isotonic (control) saline into the upper division of the trapezius muscle in two separate experimental sessions. Average rectified value (ARV) and muscle fiber conduction velocity (CV) were estimated from the surface EMG signals at 90 of shoulder flexion throughout the 2.5-min task.
RESULTS: Peak pain intensity rated on a numerical rating scale (0 - 10) during the 2.5-min task were (mean ± SE) 5.6 ± 0.6 and 0.9 ± 0.3 following injection of hypertonic and isotonic saline, respectively ($P < 0.001$). Upper trapezius showed lower ARV (ANOVA: $F = 41.9$, $P < 0.001$) and lower trapezius higher ARV (ANOVA: $F = 3.5$, $P < 0.05$) throughout the entire task following the injection of hypertonic saline (40.0 ± 7.4 μV vs 26.0 ± 5.8μV, and 12.5 ± 2.5 μV vs 25.6 ± 4.9 μV, respectively at the beginning of the contraction). No significant differences were identified for estimates of CV in all three divisions of trapezius across the duration of the task (4.7 ± 0.5 m/s, 4.5 ± 0.5 m/s, 4.1 ± 0.2 m/s, for the upper, middle, and lower division at the beginning of the contraction).
CONCLUSIONS: These findings suggest a reorganization in the coordination among the three divisions of trapezius muscle without a change in the membrane fiber properties (as assessed by CV) in response to muscle pain during dynamic movement of the upper limb. The results are in agreement with the pain adaptation model which predicts reduced activity in the painful muscle. In addition, the results demonstrate an opposite affect of muscle pain on non painful muscle subdivisions. These findings may have implications for the perpetuation and worsening of symptoms during repetitive upper limb work.

The John J. Bonica Fellowship and the European Community (project "Cybernetic Manufacturing Systems, CyberManS")

BILATERAL INCREASE IN CORTICOMOTOR EXCITABILITY FOLLOWING INTERVENTIONAL TRANSCRANIAL MAGNETIC STIMULATION (iTMS)

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AIMS: Transcranial Magnetic Stimulation (TMS) has been recently demonstrated to have potential therapeutic benefits by promoting cortical plasticity through modulation of corticospinal excitability. We have previously shown in healthy adult subjects that paired-pulse TMS (1.5ms isi) applied over M1 at 0.2Hz for 15min (known as iTMS), can raise corticospinal excitability for a period (~10min) that outlasts the intervention. Since inter-hemispheric changes in corticomotor excitability are considered to have fundamental importance in the control of voluntary movement, and recovery of motor function following unilateral damage, the aim of the present study was to investigate if the unilateral facilitation produced by iTMS influenced contralateral corticomotor excitability.
METHODS: In 11 healthy adult volunteers (7 Male, 18-45yrs), the mean amplitude of the Motor Evoked Potential (MEP) was recorded (single pulse, 110% resting motor threshold, optimal site for first dorsal interosseous muscle on each hemisphere) pre and post 15 min of iTMS (left hemisphere, 100% of resting motor threshold). The mean amplitude post iTMS was expressed as a percentage of the pre iTMS mean for each subject.
RESULTS: iTMS applied over the left M1, produced a post intervention increase in MEP amplitude for the right FDI that peaked at 365% ± 44% SEM ($p<0.000$) of baseline, with a corresponding increase of 154% ±25% ($p<0.05$) in the contralateral hemisphere.
CONCLUSIONS: The profound increase in corticomotor excitability following iTMS is partially transferred to the contralateral hemisphere. This finding strengthens the role of each hemisphere influencing the output of the contralateral hemisphere and is contrary to the current opinion that the net action of one hemisphere is to inhibit the output of the contralateral hemisphere. It remains to be determined whether this effect is acting by direct transcallosal pathways, or is a more elaborate and independent phenomenon.

THE EFFECTS OF ACTIVE AND PASSIVE TRUNK STIFFNESS ON SPINE CONTROLLABILITY

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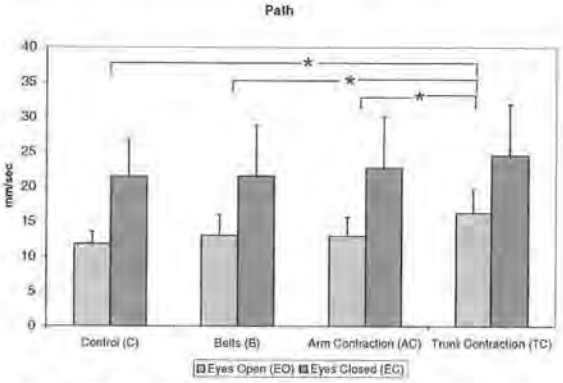
AIMS: Degraded neuromuscular control in an inherently unstable spine may explain injury under low-level loading or unexpected perturbations. This paper focused on the trade-off between stiffness and controllability of the spine. We hypothesized that an increase in trunk stiffness would degrade neuromuscular control, and further hypothesized that signal dependent noise (SDN), resulting in increased muscle force variability, was responsible for this impairment.
METHODS: Unstable seated balancing was performed during 4 randomized conditions: normal balancing (control), trunk muscle coactivation (active stiffness), arm coactivation (attention control), and belt (passive stiffness). Center of pressure (CoP) and EMG data were collected during three 20 second trials. Degraded neuromuscular control was reflected in increased CoP velocity.
RESULTS: Results for Path showed that the main effect of Eyes and Condition were significant (see figure below), but Direction of Path and interactions were not. Trunk muscle coactivation resulted in significantly higher CoP velocities than the control ($p<.001$) and arm coactivation ($p<.001$) conditions. EMG data confirmed that the trunk coactivation condition had significantly higher muscle activity than the control ($p=.001$) and arm coactivation ($p=.001$) conditions. The belt condition, which increases passive trunk stiffness, showed no degraded neuromuscular control, but interestingly produced slightly lower levels of trunk muscle activity than the control condition ($p<.001$).
CONCLUSIONS: Increased active trunk stiffness from muscle coactivation degraded neuromuscular control. Since the arm coactivation condition showed no impairment, attention demands cannot explain this result. Furthermore, since passive trunk stiffness from wearing a belt did not affect performance, it is believed that SDN from increased trunk muscle recruitment, and not an altered postural control strategy from increased joint stiffness, was responsible for the impairment. This study clearly showed that a trade-off exists between active trunk stiffness and controllability. Considering the growing evidence that neuromuscular control is affected in the low back pain population, new insight into the rehabilitation of motor control might be gained from a better understanding of this trade-off.



Path (CoP velocity) grouped by condition (indicates $p<.01$)*

DIFFICULTIES IN ADJUSTING MUSCLE ACTIVATION PATTERNS TO STABILIZE THE SPINE UNDER EXTERNALLY LOADED SITUATIONS

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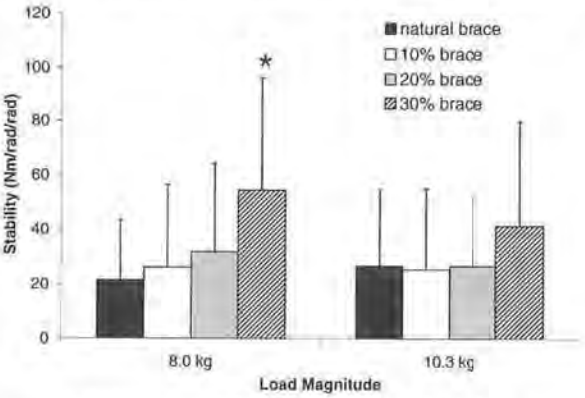
AIMS: Spine stability requires trunk muscle coactivation. This demands motor control skill which differs across people and situations. The quick release protocol may offer insight into the motor control scheme and the subsequent affect on spine stability. The purpose of this study was to quantify the ability of individuals to abdominally brace the externally loaded trunk and assess their success in achieving and enhancing appropriate spine stability.
METHODS: Ten healthy male individuals sat, torso upright, in an apparatus designed to foster a neutral spine position. They were instructed to support a posteriorly directed load (either 8.0 or 10.3 kg) to the trunk in either their naturally chosen manner, or by consciously activating, by means of a biofeedback



Stability levels averaged over the 50 ms prior to load release.
** indicates a significant difference from the natural, 10% and 20% brace levels*

device, the abdominal muscles to 10%, 20%, or 30% of maximum ability. The externally applied load was then quickly released, thereby unloading the participant. Muscle pre-activation patterns, spine stability, and kinematic measures of trunk stiffness were quantified.
RESULTS: Participants were able to effectively stabilize their spine by supporting the load in a naturally selected manner. However, all participants demonstrated difficulties in successfully adjusting muscular activation patterns to achieve increases in spine stability. A significant interaction ($p=0.0336$) between brace level and load was found for the the measure of spine stability (Figure). Unbalanced muscular coactivation schemes often occurred when attempting to overdrive naturally chosen coactivation patterns. This resulted in the level of spine stability decreasing in 59 percent of the 10% brace trials as compared to the natural brace trials, in 35 percent of the 20% brace trials as compared to the 10% brace trials, and 17.5 percent of the 30% as compared to the 20% brace trials.
CONCLUSIONS: Individuals in an externally loaded state appear to select a natural muscular activation pattern appropriate to sufficiently maintain spine stability. Relatively small conscious adjustments in individual muscles around this natural level may actually decrease the stability margin of safety. More robust coactivation levels (30% MVC) appear to create a more balanced contraction across all muscles to ensure enhanced stability.

DEEP AND SUPERFICIAL ABDOMINAL MUSCLES SHOW DIFFERENT ACTIVATION PATTERNS IN A HOLD-RELEASE SITUATION

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Karolinska Institutet, and University College of Physical Education and Sports, Stockholm, Sweden

AIMS: The aim was to investigate coordination patterns of deep and superficial abdominal muscles, using intramuscular EMG recordings, in response to a perturbation applied to the trunk during ongoing agonist or antagonist activation, i.e. a "hold-release" paradigm [1].
METHODS: Ten healthy male volunteers participated. Intramuscular fine wire EMG was recorded bilaterally from the rectus abdominis (RA), obliquus externus (OE), transversus abdominis (TrA) and erector spinae (ES) muscles. The subjects lay on their right side on a horizontal swivel-table with pelvis and lower limbs strapped to an immobile part and the trunk to a movable part of the table [2]. The two parts were connected via a hinge allowing the trunk to move either in flexion or extension (centre of rotation at L3 level). A steel cable, with a fixed attachment to the movable part and an electromagnetic attachment to a sturdy metal frame, provided isometric resistance. Applied force was measured with a force transducer and the signal fed back to the subject as a line to be matched on an oscilloscope. With the subject maintaining trunk flexion or extension force at either of three preset levels (30%, 50% and 70% of MVC, three trials per level and direction, spine in a neutral position) the resistance was suddenly released by cutting the power to the electromagnet. The instant of release was measured with an accelerometer. The subjects were instructed to resume the neutral position as soon as possible. EMG signals were analysed with respect to amplitudes and timing of start and end of activation. From these analyses in progress results are presently available for EMG timing in the trials where the release induced a trunk flexion.
RESULTS: Averaged over all three force levels and right and left sides, the sustained activation of RA and OE was found to end 83 ms (SD 11) and 91 ms (SD 21), respectively, after the release. The subsequent start of the antagonist ES activation occurred 128 ms (SD 34) after the release. Interestingly, the deep abdominal muscle TrA responded in a similar manner as ES in the majority (80%) of the trials, mean start of increased activity being 111 ms (SD 24). OE showed a similar response as TrA in 20% of the trials.
CONCLUSIONS: In response to a perturbation where isometric resistance to trunk flexion suddenly was released, the transversus abdominis muscle generally responded independently from the superficial abdominal muscles and in concert with the back muscles. One possible effect of this activity could be an augmentation of the intra-abdominal pressure to assist in back extension [2].

[1] Radebold A, Cholewicki J, Panjabi MM, Patel TC. Muscle response pattern to sudden trunk loading in healthy individuals and in patients with chronic low back pain. Spine 2000;25(8):947-54.
[2] Hodges PW, Cresswell AG, Daggfeldt K, Thorstensson A. In vivo measurement of the effect of intra-abdominal pressure on the human spine. J Biomech 2001;34(3):347-53.

NEUROMUSCULAR INDEPENDENCE OF THE ABDOMINAL WALL AS DEMONSTRATED BY MIDDLE-EASTERN STYLE DANCERS

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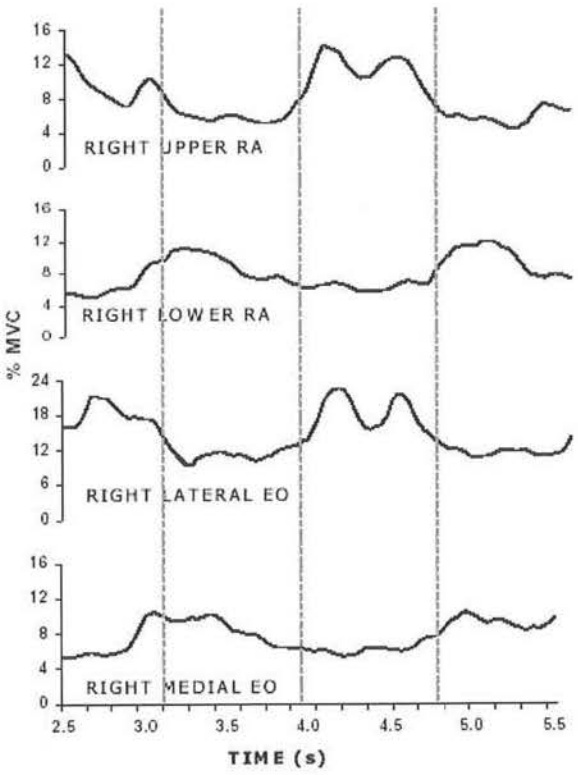
2) Universidad Miguel Hernández de Elche, Alicante, Spain

AIMS: There is controversy in the literature as to the neuromuscular independence of portions of the same muscle. We examined the ability of middle-eastern style dancers to isolate upper/lower rectus abdominis (RA) as well as medial/lateral external oblique (EO) muscles, recognizing that this population may have a unique ability to recruit muscle portions segmentally.
METHODS: 9 females, experienced in the art of middle-eastern dance, volunteered for the study. Each participant completed a total of 20 varying dance movements as well as 12 planar movements, as demonstrated to each by an instructional video. Trunk muscle electromyographic (EMG) data was collected on 16 trunk muscle segments bilaterally, as well as spine motion (3-Space) and video data.
RESULTS: A clear anti-phase pattern was demonstrated between upper/lower RA and medial/lateral EO during a dance motion which required isolated hollowing of the upper abdomen, followed



by hollowing of the lower abdomen (Figure). During rapid "wave-like" contractions of the abdominal muscles (top to bottom), at a frequency of approximately 1.25 Hz, many participants demonstrated a time lag of up to 0.3 seconds between the onset and/or peak of upper RA when compared to lower RA.
CONCLUSIONS: Analyzing movement patterns in a unique population, highly skilled in torso control, provided insight into the neuromuscular independence that is possible with specific training. This group demonstrated clear evidence of the ability of isolate upper from lower RA, and medial from lateral EO, which appears to be very rare in the normal population.

LUMBOPELVIC MUSCLE RESPONSES TO PROGRESSIVE LOADING AND REDUCED PREDICTABILITY

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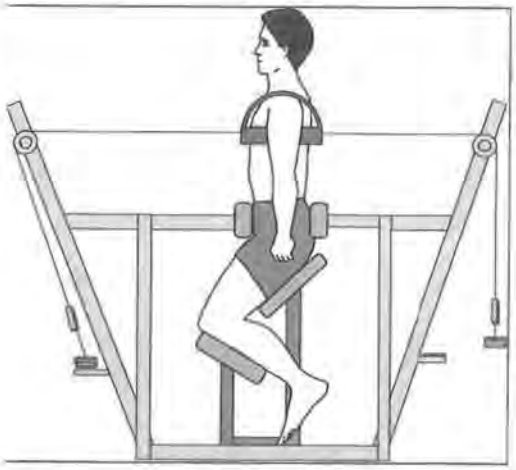
AIMS: Lumbopelvic stability relies, amongst other factors, on co-contraction of the lumbo-pelvic muscles. Changes in load and predictability are expected to affect the associated control strategies. We hypothesized that co-contraction of the trunk muscles would increase with increasing load and with reduced predictability. On the basis of previous data, we also predicted that the activity of transversus abdominis (TrA) and the deep fibres of multifidus would be independent of the direction of force.
METHODS: Eleven healthy subjects were placed in a custom built loading frame and performed ~5 s isometric efforts into flexion and extension to meet submaximal target loads of 5, 10, 15 and 20 kg, presented randomly. The tasks were then repeated with the knowledge that the load would be released after a random delay during the isometric hold. Maximum voluntary contraction (MVC) efforts were also performed isometrically in both directions. EMG recordings were made from 8 trunk muscles. Surface electrodes were placed over the lumbar and thoracic erector spinae, rectus abdominis, obliquus internus and externus abdominis (OI and OE). Bipolar fine-wire intramuscular electrodes were inserted into TrA and the superficial and deep multifidus (SM and DM). RMS EMG amplitudes were calculated and normalized to the subject's MVC. Data was analyzed using repeated measures ANOVA and post hoc analyses.
RESULTS: In the MVC extension efforts there was increased co-contraction with increased EMG activity present of all 8 of the trunk muscles. In the MVC flexion efforts, EMG activity of all muscles increased except for DM. TrA EMG was the same in both directions.
When subjects flexed their trunk to the submaximal target loads, EMG activity of OE increased at the 5 kg load interval, the other abdominal muscles increased at 10 kg. However, none of the paraspinal muscles increased their EMG activity above baseline levels in the upright starting position. In the submaximal extension tasks, paraspinal muscle EMG increased at all levels of force. TrA EMG also increased in the 15 and 20 kg intervals of the extension task, but there was no concurrent increase in EMG of the other abdominal muscles.
In the unpredictable trials, the EMG activity of the respective agonist muscles was less than in the predictable trials at the higher force levels. Co-contraction did no increase with reduced predictability in either direction. However, unlike the other muscles, TrA EMG did not decrease when predictability was reduced.
CONCLUSIONS: Although co-contraction increased during MVC efforts, contrary to the hypothesis, there was no evidence of increased co-contraction of the lumbo-pelvic muscles during submaximal loading, except for TrA. Under these conditions, the activity of TrA, but not DM, was found to be active independent of the direction of force. When predictability was reduced there was a change in strategy for the primary agonists, but this involved a reduction in EMG activity and there was no increase in co-contraction. This study also provides further support for the unique role of TrA in lumbo-pelvic stability in both flexion and extension loading tasks.



Custom built loading frame for subject positioning and progressive isometric load applications via load cells and electromagnetic plates

TRUNK MUSCLE RESPONSES TO SUDDENLY APPLIED LOADS BEFORE AND AFTER A PROLONGED PERIOD OF STANDING

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AIMS: An observed relationship between delayed motor control responses to sudden trunk perturbations and the development of low back pain suggests that inadequate muscular control may decrease spinal stability, potentially resulting in an increased chance of low back injury. However, no study has examined trunk responses to a suddenly applied load prior to and following a task that has resulted in low back discomfort (LBD). The current study examined individuals' responses to a suddenly applied load to the hands prior to and following a prolonged standing period, a task shown to elicit LBD. The aim of this study was to determine if the presence of LBD, rather than a low back injury, alters the response to a suddenly applied load.
METHODS: Thirteen participants held a container designed such that a load could be released (6.78 kg at a 2 cm height) into the container without the participant knowing the timing of release. Five perturbation trials were conducted prior to and following exposure to a 2-hour period of standing. Response variables examined were baseline electromyography (EMG) of four bilateral trunk muscles (2 extensor, 2 flexor), response magnitude in EMG following the applied load (50ms before versus 350ms after perturbation), muscle on-set latency (up to 150ms following the perturbation), and the frequency of muscle on-set (percentage of trials when a specific muscle responded to the applied load). The development of LBD was monitored using visual analog scale ratings of perceived discomfort. Two-way ANOVAs were used to determine the effect of pre versus post standing, and LBD versus no LBD, on the response variables.
RESULTS: Seven of the participants developed LBD following the 2-hour standing period. All muscles showed a general trend of increasing activation in response to the applied load. Most interesting was a significantly increased frequency of on-set in the erector spinae (ES) muscles in those who developed LBD versus those who did not. No differences between the LBD and no LBD groups were found for any of the other variables. With respect to pre versus post standing, a significant decrease in the response magnitude of left rectus abdominis and a significant increase in the response magnitude of left thoracic ES were observed following the standing period.
CONCLUSIONS: The two most important findings of this study were that all muscles (including seemingly antagonist abdominal muscles) responded by increasing activation following a suddenly applied load, and the higher frequency of response in the ES muscles in those who developed LBD. Although the applied

load resulted in a trunk flexor moment, responses in the abdominals were observed indicating co-contraction is required to recover from suddenly applied loads. Interestingly, the individuals who developed LBD activated their ES muscles in response to the load more often than those who did not. No other variables (onset times, response magnitudes) were found to be different between the LBD and no LBD groups, suggesting that a key to identifying those who are most susceptible to LBD is the likelihood to elicit a muscular response to small trunk perturbations.

VOLUNTARY ACTIVATION OF TRAPEZIUS DURING UNILATERAL AND BILATERAL VOLUNTARY CONTRACTION

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AIMS: Isometric maximal voluntary force in the trapezius muscle has been shown to be decreased among workers with selfreported shoulder neck pain. To identify if this is due to trapezius muscle weakness or impaired neural drive measurement of voluntary activation would be essential. In limb muscles voluntary activation is often tested in unilateral contractions since maximal voluntary bilateral contractions have been reported to produce less force than unilateral contractions. This decrease has been attributed to inhibitory neural interactions between homologous muscles. Such constraints may not apply in the trapezius muscles, which are commonly recruited bilaterally. We evaluated twitch interpolation as a method for measuring voluntary activation in trapezius and compared force and voluntary activation during bilateral and unilateral MVCs of trapezius.
METHODS: Eight subjects (25-61 years) took part in the experiment. Subjects sat on a chair with the feet suspended over the floor. Force transducers were applied over the acromion of both shoulders. The subjects lifted the right shoulder or both shoulders against the fixed force transducers. Visual feedback of the target force and force trajectory was given in front of the subject. Stimulation of the accessory nerve in the neck was used to evoke maximal twitches in right trapezius. Surface EMG was recorded from the upper, middle and lower part of the right trapezius and from the upper part of the left trapezius. First stimulation was given during a series of bilateral contractions at different force levels. This was performed to determine that twitch interpolation could be used to measure voluntary activation of trapezius and that the relationship between voluntary force and the amplitude of the superimposed twitch was near linear. Secondly, unilateral and bilateral MVCs were performed with twitch interpolations.
RESULTS: The twitch-like increments in force (superimposed twitches) evoked during different strength voluntary contractions were linearly related to voluntary force (r^2=0.80 to 0.98). Hence, voluntary activation could be quantified by twitch interpolation with this stimulus. Maximal voluntary force on the right shoulder was greater in unilateral than bilateral MVCs (92.7±2.9% and 82.3±5.8% MVC respectively) but voluntary activation was similar (88.6±9.6% and 91.7±5.2%). EMG was also similar for all three electrode positions over right trapezius.
CONCLUSIONS: Voluntary activation of the trapezius muscle can be measured with twitch interpolation by stimulating the accessory nerve in the neck. This may in the future prove useful clinically. Despite better postural stability in bilateral contractions and crossed facilitation between trapezius muscles, subjects were stronger in unilateral efforts. However, this was not due to a deficit in neural drive. The greater postural stability in bilateral contractions suggests that the trapezius strength is best tested by raising both shoulders since voluntary activation is not reduced by the requirement for drive to both muscles.

DIFFERENTIAL ACTIVITY OF DEEP AND SUPERFICIAL THORACIC PARASPINAL MUSCLES DURING VOLUNTARY ARM MOVEMENTS

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AIMS: 1) To determine whether anticipatory activity of the thoracic paraspinal muscles is associated with bilateral and unilateral arm movements, 2) to determine whether thoracic multifidus/rotatores and longissimus thoracis are differentially active during arm movements, and 3) to compare the activity of these muscles between regions of the thoracic spine (T5, T8, T11).
METHODS: Recordings of electromyographic activity (EMG) of the deep (multifidus/rotatores) and superfiical (longissimus thoracis) paraspinal muscles on the right at T5, T8 and T11 were made with fine-wire electrodes in ten healthy subjects (without neck, thoracic, or low back pain). Subjects performed fast bilateral and unilateral flexion and extension of both arms in response to a visual stimulus. EMG amplitude was measured during 25 ms time intervals for 150 ms before and 400 ms after the onset of activity in the anterior or posterior deltoid.
RESULTS: During biliateral arm flexion movements, multifidus and longissimus had two bursts of activity, an early burst that was initiated prior to anterior deltoid onset and a late burst initiated between 275-325 ms after the onset of deltoid. During arm extension movements both multifidus and longissimus were active in a single burst, 125-175 ms after the onset of posterior deltoid. Therefore, anticipatory acitivity of both multifidus and longissimus was associated with arm flexion movements, but not with arm extension movements. Although similar in these features of the response, the muscles were differentially active during unilateral arm movements depending on the direction of trunk rotation that was induced by the arm movement. Longissimus had greater EMG activity with left arm flexion (which induced left trunk rotation) than with right arm flexion (which induced right trunk rotation)($p<0.03$). Multifidus showed the opposite pattern, with greater activity with right arm movements compared to left arm movements ($p<0.04$). There were no differences in the response of the multifidus and longissimus muscles between regions of the thorax (T5, T8, T11)($p = 0.98$).
CONCLUSIONS: Thoracic multifidus and longissimus are similarly active in response to sagittal plane perturbations of the trunk, but are differentially active during unilateral arm movements which induce rotation around the vertical axis in addition to the perturbation in the sagittal plane. These findings are consistent with anatomical data that suggest that the muscles control opposite rotational torques. The differential activity between the deep and superficial paraspinal muscles highlights the complex function of these muscles and has implications for use of surface electrodes in future studies of paraspinal muscle activity.

A STUDY OF MOTOR CONTROL FOR LOAD ON TASK USING ELETROMYOGRAPHIC SIGNALS

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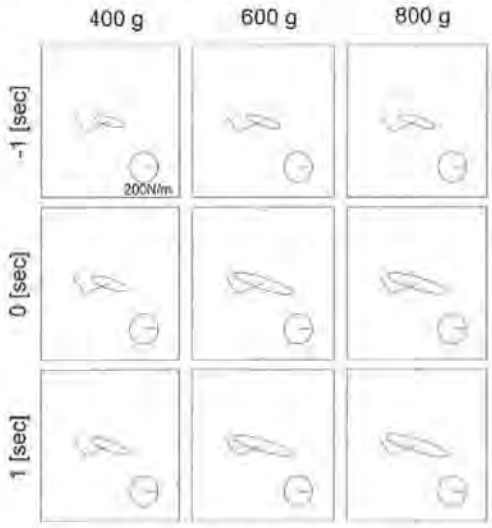
AIMS: When we interact with environments, the motor control mechanism could compose the computational mechanism of perception. While undertaking tasks related to handling objects, we have to control motor commands corresponding not only to limb properties but also object properties. The aim of this paper is to examine how the human perceive the object weight in environments. We focus on load-on task, and clarify the goal of learning motor skills and verify the way we control impedance.
METHODS: We used a string-based haptic interface 'SPIDAR' to provide each subject the weights as the same condition. Subjects were seated in front of a large screen and asked to load on the virtual object which was generated by computer. To estimate the hand force and equilibrium point (EP), the mathematical musculoskeletal system model (MMSM) was

proposed. In this MMSM method, human arm on the sagittal plane was modelled as a two-link manipulator with 6 monoarticular muscles and 2 biarticular muscles. Each mathematical muscle has the elastic property, which is represented by a linear function of motor command u and some parameters representing muscle properties such as muscle length. The rectified, filtered and normalized EMG signals could be used as motor command u of MMSM. We can also calibrate the parameters of MMSM from the relationship EMG signals and measured torque. Actually, we can estimate a time-varying joint torques and stiffness simultaneously using MMSM method. Estimated joint torque agrees well with the real joint torque of two types of force generating tasks. Therefore, the success of the torque model for various positions and all subjects would indicate that our proposed method can predict time-varying stiffness using only EMG signal measurement. This is first trial to estimate time-varying stiffness and EP.

RESULTS: We could estimate time-varying stiffness and hand force and measured the change of the hand position while subject conducted load-on-task using SPIDAR system. Figure shows the change of stiffness ellipse when the subject load on each virtual object. The major axes of stiffness ellipses were oriented toward the subject's shoulder like the characteristic on the horizontal plane. And we could observe that stiffness increased in proportion to the weight. The size of ellipses were almost same between that of just before the load-on and that of after the load-on. This means that the CNS produced and maintained co-contraction before the load-on. From this result, the CNS would control not only the EP but also joint stiffness as well. A one factor ANOVA (DOF (3, 99), α=0.05) was used to investigate which is closely related to motor control for the weight, EP or stiffness. When significance level was seen, carry out the multiple comparison test of Tukey-Scheffe. As a result, we obtained that stiffness is more closely connected with the perception of the weight than EP.



Change of the stiffness ellipses for the weights

CONCLUSIONS: Our results show that the goal of learning motor skills under load-on task is to maintain the hand position and that humans produce force with co-contraction and increase stiffness level according to the weight of the object.

IS PROPRIOCEPTION REDUCED IN SUBJECTS WITH SYMPTOMATIC ELBOWS?

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3) Parker Institute, Frederiksberg Hospital, Frederiksberg, Dk

AIMS: The aim of this cross-sectional study was to test whether proprioception was reduced locally in the elbows or generally (also in the knees) among subjects with unilateral or bilateral epicondylitis lateralis (LE) compared with a group of healthy controls.

METHODS: Proprioception was measured in both elbows and knees as an active-active joint position sense (JPS) and threshold to detection of passive movement (TDPM) with velocity of 1°/s. Fifteen females with LE (mean age 47.8, SD 7.5 years) and twenty-one age-matched healthy controls (mean age 45.2, SD 8.8 years) participated in the study. Absolute Error, AE, was calculated for JPS as the mean difference between target and estimated angle with three repetitions. For TDPM AE was calculated as the mean difference between motor start and response with six repetitions. Variable Error, VE, of TDPM was calculated as the mean standard deviation of the differences.

RESULTS: Data was tested in a general linear regression model. AE of JPS and VE of TDPM were poorer in the LE-diagnosed elbow when compared to the elbow of the healthy control group (mean AE: 8.9°, 6.0°, p=0.037; mean VE: 0.8°, 0.4°, p=0.033). In AE of TDPM there was no difference in the elbows between the two groups. Neither a difference was seen in the proprioception measures with respect to the knees between the two groups. For the LE-subjects AE of JPS was poorer in the LE-diagnosed elbows alone and both elbows together compared to their knees (mean AE of LE-diagnosed elbow: 8.9°, knees 5.4°, p=0.028; mean AE of both elbows: 7.8°, knees 5.4°, p=0.043). The same pattern was seen in the healthy control group for AE of JPS, though not significant. VAS-ratings (0-100) of pain, concentration difficulty, stress, exhaustion and boredom performed before and after each JPS and TDPM session were all below 6, indicating a limited effect on the measurements.

CONCLUSIONS: Most of the studied proprioception measures were poorer and thus reduced in the LE-diagnosed elbow compared to elbows of healthy controls. As there was no difference in the knees of the two groups these results indicate a local more than a general effect on proprioception in this patient group. The precise mechanism behind that is still unclear. Proprioception measures may be used as supplemental outcome measures of both acute and longterm effects of future physiotherapeutic and medical interventions in LE subjects.

THE CONTRIBUTION OF THE WRIST AND ELBOW JOINTS DURING SINGLE FINGER TAPPING

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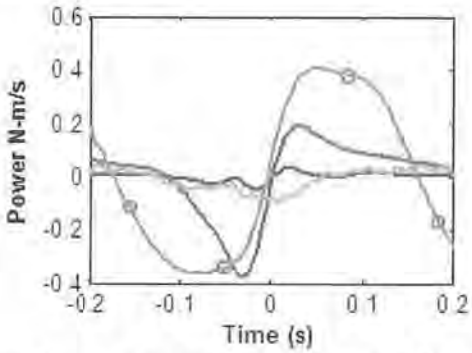
AIMS: We aimed to determine the role of the wrist and elbow joints during single finger tapping. The study is motivated by the fact that during computer use the muscles of the forearm and shoulder are at risk for the development of musculoskeletal disorders (Gerr et al. *AJIM* 41: 221-235 2004). Discussion about the etiology of these disorders usually referes to the static efforts associated with maintaining the position of the hand and arms in the presense of gravity; however, typing and tapping are a dynamic task where wrist accelerations approach levels associated with high risk industrial jobs (Serina et al. *Ergonomics*. 42: 938-951: 1999).

METHODS: Five human subjects (3M,2F) ranging in age from (24-40) tapped with their index finger at a rate of 3 taps per second on a rigid surface and an apple alps keyswitch, both mounted on a single-axis force plate. The motion of the upper extremity and fingertip was measured using an optotrack 3-d motion analysis system. The upper extremity was modeled as four rigid links (index finger, hand, forearm and upper arm). The segmental kinematics and inverse dynamics estimated joint torques for the metacarpal-phalangeal (MCP), wrist, elbow, and shoulder joints. For our purposes, kinematic (geometric) and kinetic (joint power) relationships defined the contributions of each joint to the tapping process (Zajac et al. *Gait Posture* 16: 215-232, 2002).

RESULTS: The magnitude of the vertical fingertip motion during

the tapping consisted of a combination of elbow, wrist and finger joint movements. For tapping on a hard surface 46%, 45%, and 9% of the vertical fingertip movement were a result of movement of the MCP, Wrist and Elbow joints, respectively. For tapping on a keyswitch, 27%, 56%, and 18% were a result of the MCP, wrist and elbow joints, respectively. The differences in these kinematics between the two different surfaces (rigid surface versus the keyswitch) were statistically significant (paired t-test, $p<0.03$). The average kinetic energy for a tap cycle doubled from 0.0012 N-m for the rigid surfuce to 0.0024 N-m for tapping on the keyswitch. For taps onthe rigid surface, 33%, 48%, 8%, and 3% of the kinetic energy were attributed to the finger, hand, forearm, and the upperarm, respectively. For taps on the keyswitch, 19%, 60%, 12%, 2% of the kinetic energy were attributed to the finger, hand, forearm, and upperarm, respectively. The joint powers suggest that the wrist and elbow are large contributors to the tapping action (Figure). For both conditions the wrist and elbow account for over 70% of the average joint powers for the tapping action. The contribution of the elbow joint increased from 36% for the rigid surface to 55% for taps on the key.

CONCLUSIONS: The kinematic and kinetic data indicate that the wrist and elbow contribute significantly to the tapping action and this contribution is larger with the inclusion of movement in the task requirements (keyswitch condition).



Average joint power across 16 taps on a keyswitch for the MCP Joint(Blue-solid), Wrist (Green-dashed), Elbow (Red-dotted), and shoulder (Cyan-semidashed). Taps were aligned at the maximum force (time=0). The vertical lines indicate A) the start of the down stroke, B) the beginning of contact, C) end of contact, and D) the beginning of next downswing

NEURAL CONTROLLER FOR BALLISTIC MOVEMENTS OF THE UPPER ARM

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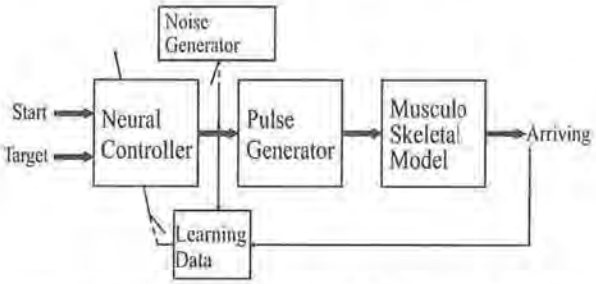
AIMS: This work deals with the development of an artificial neural controller of an upper human arm model during planar ballistic movements. The overall system should achieve the ability to perform reaching tasks within a 2D workspace without any feedback information about the followed trajectory. The inverse dynamic control model of the arm should be acquired by the neural system by means of a training phase; a learning paradigm different from an offline batch training is necessary to achieve a correspondence with a physiological system. The movements should be defined by both the kinematic aspects and the muscular activations typical of ballistic tasks.

METHODS: Three principal blocks define the motor control scheme of the developed system. Each block has a specific role in the perception-action transformation: the first module is the Artificial Neural Controller which is dedicated to the elaboration of the proprioceptive information by means of synaptic modifications; the second one is the Pulse Generator which, elaborating the outputs of the controller, generates the neural inputs necessary to the activation of the muscular system; the last block is the effector, comprised of 4 muscle-like actuators acting on a 2 degree of freedom structure. On the basis of Neurophysiology, the model mimics the exploration process, by learning the work plane only moving the arm, and remembering the neural inputs utilized to reach the end position: there is a mapping between neural commands and reached positions.

RESULTS: The behaviour of the 'controller-controlled object' system in response to different reaching tasks in the workspace was analyzed. For a set of 3000 random movements within the work plane, the system shows a mean error position of about 5.0cm with a standard deviation of about 4.3cm. Other important aspects of these simulations concern the relationship between the temporal muscular synergies and the direction of the tasks, the low correlation between the error position and the length of the movements and the high correlation between the peak velocity and the length of the movement. These results are in agreement with those obtained from the acquisition tests on human beings.

CONCLUSIONS: A neuron motor control system for a model of the upper limb has been developed. The control of the arm is carried out by a neural network that simulates the internal model managing the feed forward aspect of the movement, using only information about starting and final positions. The almost optimal behaviour analyzed for planar ballistic movements can be ascribed both to the arm model and to the learning algorithm which let the system exploit the power of the neural networks in order to create a fast, physiological and accurate controller.



Motor and Learning control scheme of the proposed model

PREDICTION OF ELBOW MECHANICAL IMPEDANCE WITH SURFACE EMG

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AIMS: The long-term objective of this research effort is to relate surface EMG signals to the mechanical impedance of the human elbow. Mechanical impedance of the musculo-skeletal system has been measured for a number of joints, primarily during well-controlled laboratory conditions. Given its importance for motor control studies, there is a need to develop a technique capable of predicting joint mechanical impedance in more complex daily tasks. Our overall aim is to use surface EMG for that purpose. The specific goal of this study was to develop a mechanical apparatus and protocol to estimate the parameters of a linearized second order joint mechanical impedance model (i.e., inertia, damping and stiffness), for future use in EMG to mechanical impedance studies.

METHODS: Subjects were seated on a fixed chair, with their shoulder at 90 degrees abduction, and their elbow at 90 degrees flexion in almost full supination (as shown in Figure). The hand/forearm was strapped in a cast attached to a two DOF joystick which could shake their limb in the horizontal plane, over a ±15 degree flexion range. Subjects were asked to maintain a fixed level of biceps activation, while a 1-6 Hz bandwidth perturbations pseudorandom force perturbation was exerted on the cast at the contact point with the joystick. The resulting motion of the forearm at the cast location was measured with a high resolution encoder. Using least squares techniques that related the angularto the applied torque perturbations, system identification of the elbow inertia, damping and stiffness was performed. In this preliminary investigation, tests were conducted with the subject passive (fully relaxed), and during low and high elbow constant

co-contraction levels. Tests were also conducted by replacing the human subject by a mechanical mass-spring system to validate the system identification process.
RESULTS: Results showed accurate estimates of the inertia and stiffness of the mechanical mass-spring system. The prediction of exerted force calculated from these impedance parameters showed excellent correlation with actual exerted force by the joystick (r^2>0.95). However, inertia estimates of the human subjects (apparent inertia about 0,8 Kg) were only valid for passive conditions (r^2=0.90). Stiffness values ranged from 580 N/m (low co-contraction level) to 850 N/m (high co-contraction level), while damping was 32 and 37 Ns/m, respectively. Mathematically removing inertial forces, so that only damping and stiffness needed to be estimated, increased stiffness values to 800 and 1250 N/m, respectively, while damping was unchanged. These damping and stiffness values are in the range of those already described in the literature. However, results showed medium correlation (r^2= 0.75).
CONCLUSIONS: Relating surface EMG to elbow mechanical impedance may require a more complex dynamic model than a linear second order system.

Top view of forearm attached to two DOF joystick

THE INFLUENCE OF THE FLEXOR DIGITORUM BREVIS MUSCLE ON POSTURAL STABILITY

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AIMS: The purpose of this study is to investigate the effects of the *Flexor Digitorum Brevis* (FDB) muscle in postural control in isolation from other muscles.
METHODS: Two questions are studied: (i) the effects of external electrical muscle excitation on the centre of pressure (COP) and (ii) the ratio of the maximum torques generated by the FDB and the *Soleus*. Ten normal subjects were used in both paradigms. In the first paradigm, the subject was requested to stand upright over a force platform with eyes open (EO) or eyes closed (EC) during 60 s. Electrical stimuli (pulse) of 0.2 ms duration were bilaterally applied to the tibial nerve at the internal malleolus, to elicit an M wave amplitude of 20 or 30% of M_{max}. The stimulation pattern consisted of 1 s duration bursts of pulse stimuli, occurring at every 5 s, i.e., the burst occurred at 0.2 Hz. The pulse rate within each burst was 16 Hz. Surface electromyography electrodes were placed on the following muscles: FDB, Soleus, Tibialis Anterior and Vastus Mediallis of both legs. Each subject normally performed two trials each, with EO and EC, without and with nerve stimulation. In order to avoid fatigue, each condition was performed at least with 1 min elapsed between each trial. Synchronous averaging of each muscle's EMG with respect to the pulse stimuli was computed for each trial. The cross-covariance (with pre-whitening when needed) between the COP and the stimuli was computed as well as the power spectrum of the COP and EMG. For comparison purposes, the effects of cutaneous stimulation were also analyzed. In the second paradigm the Soleus and the FDB muscles (one at a time) were stimulated bilaterally to generate the corresponding M_{max}. The measured variable was the sagital moment in each condition. The ratio between the sagital moments of the FDB and the Soleus were computed and expressed as a percentage.
RESULTS: Data obtained from the synchronous averaging of post stimulus EMG showed a clear M wave at the FDB and no coherent muscle activity at the other muscles studied. The corresponding COP variability was increased during the application of the electrical stimulation pattern. Cross covariance between the pre-whitened COP and the stimulation bursts evidenced that the COP could follow each pulse stimulus. The COP power spectrum presented a sharp peak at 0.2 Hz, which did not appear in unstimulated standing. The second paradigm showed that the ratio between the sagital moments of FDB and Soleus was equal to 5.5% in the average.
CONCLUSIONS: The absence of stimulus-related activity in leg muscles, the presence of an M wave at the FDB and the correlated variations in the COP imply that this muscle's contractions can exert an effect on the COP and hence have a role in balance control even without vision. The relatively low ratio between the sagital moments of the FDB and Soleus suggests that the FDB may preferentially have a fine tuning role in postural control. Therefore, the podal and postural rehabilitation of the FDB may have a clinically relevant impact.

A MODEL OF THE NEUROMUSCULOSKELETAL SYSTEM FOR USE IN PRE-CLINICAL TESTING OF JOINT REPLACEMENTS

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AIMS: Replacing part of the skeletal system with a prosthetic joint is likely to have an impact on the neuromuscular system. This study aims to examine this question by developing a neuromusculoskeletal (NMS) model of the upper limb, which includes feedback from muscle spindles and its interaction with descending neural drives. Such a model would be a valuable tool in predicting the long- and short-term effects of joint replacement surgery on the neuromuscular system, including any damage to mechanoreceptors in the surrounding muscles and tendons.
The elbow joint was chosen in this study. The arm is considered a single joint (the elbow), single degree of freedom (flexion/extension) system. Four muscles, the biceps brachii, brachialis, brachioradialis and triceps brachii, are included in the model. The neural, muscular and biomechanical activity of the system is simulated.
METHODS: A Hill-type muscle model has been used, where a parallel passive and active element contribute to muscle force, along with a series passive element representing tendon force [1]. Hill model parameters were found by assuming that active force could be developed at all possible joint positions, and that each tendon could stretch by 3.3%.
Voluntary feedback is included through descending neural drives and reflex activity through a modified version of the muscle spindle model described in [2] - combined, these determine the motor neuron firing rate, or neural excitation. Muscle contraction dynamics are activated by this neural activation.
The system is modelled as a closed loop, as this is the case *in vivo*. The design allows the user to test the model as a closed loop, or as an open loop system, by applying a perturbation signal at any point in the model.
To perform an initial validation of the model under isometric conditions, a series of experiments was conducted. Surface electromyography (EMG) was measured from the biceps, triceps and brachioradialis muscles of 12 subjects, during constant force isometric contractions at a range of force levels and joint angles,

for both extension and flexion of the elbow. The RMS amplitude of the EMG signal was taken as an approximation of muscle activation, and was used to drive the NMS model for each force level and joint angle. Experimental and simulated data were compared.
RESULTS: Under static conditions, the model remained in the steady state throughout the simulation, at all joint positions. Good agreement was found between experimental and simulated data. Under dynamic conditions, the model responded in a physiologically realistic manner to a changing parameter within the system.
CONCLUSIONS: The NMS model presented here provides a good approximation of the behaviour of the NMS system of the elbow joint under both dynamic and static conditions, and has been validated under isometric conditions. The next step in this study will involve experimental validation of the model under dynamic conditions. It will then be used to examine changes in the neural control patterns in response to variations in the skeletal system parameters.

[1] Zajac, F.E., *Crit Rev.Biomed.Eng*, vol. 17, no. 4, pp. 359-411, 1989
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EFFECT OF UNILATERAL ELECTRO-ACUPUNCTURE ON FUNCTION OF IPSILATERAL AND CONTRALATERAL TIBIALIS ANTERIOR MUSCLE

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AIMS: It is known that unilateral resistance exercise or electromyostimulation training can increase muscular strength not only in the trained limb, but also in the homologous muscle of the contralateral limb. The principle of using unilateral therapy to treat conditions of the contralateral limb has been previously applied in traditional Chinese medicine. The primary aim of this study was to investigate whether unilateral electro-acupuncture would alter muscle strength in the treated and the contralateral limb. A secondary aim was to validate a statistical model for assessment of EMG-force relationship in response to the training.
METHODS: Sixty college-aged healthy male subjects were randomly allocated into four groups: electro-acupuncture (EA), resistance training (RT), combined EA and RT (ER), and control (CG). Subjects in the experimental groups trained the right tibialis anterior muscle in dorsiflexion exercise three sessions per week for 4 weeks. In EA, electro-acupuncture was delivered to the acupoints of Zusanli and Xiajuxu, which are located on the muscle belly of tibialis anterior, for ~15min, with gradually increased pulse frequency of 20-40Hz and intensity of 10-40V. The RT performed eccentric dorsiflexion at 30deg/sec on Cybex dynamometer for ~15min, with progressively increased 3-5 sets of 3-5 contractions. The ER combined protocols of RT and EA in each session. The CG kept normal daily activities without training. The dorsiflexion strength was measured in isokinetic, isometric, and isotonic tests, and surface EMG was recorded in the isometric and isotonic tests, before and after the training period. A three-way repeated measures ANOVA was performed to examine the interactions between groups, training, and limbs. Mean EMG amplitude of ~3s period was obtained from each contraction. Natural logarithm transformation was perform on EMG data to normalise distribution, before EMG-force relationship was analysed using MLwiN program. Mixed models were fitted with two levels of random variation. Residual maximum likelihood estimates were obtained, while nested models were compared using the -2loglikelihood statistics from maximum likelihood (ML) fits.
RESULTS: Strength of the trained limb improved significantly ($P<0.05$) in all training groups and in all three types of tests. A novel finding was that cross education was observed in both EA and ER groups in isokinetic (+4.6%, +5.8%, respectively) and isotonic (+15.2%, +30.0%) tests, and in RT and EA groups in isometric test (+9.5%, +12.2%, all $p<0.05$), while the control group showed no significant change. The EA and ER groups also showed a significantly higher isotonic strength in both limbs, and the ER group also showed significantly higher isokinetic strength in the contralateral limb, than that of the control group after training ($P<0.05$). Significant increase in EMG amplitude of the contralateral limb in isometric testing was found in the EA and ER and in isotonic tesing of the EA group.
CONCLUSIONS: It is a novel finding that electro-acupuncture at the selected points improved muscle strength not only in the trained limb, but also in the contralateral limb. This unique effect of electro-acupuncture and its underly mechansim warrents further investigation.

THE EFFECT OF MUSCLE FATIGUE ON MOTOR CONTROL IN THE KNEE JOINT

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AIMS: The effect of the lower extremity muscle fatigue on proprioceptive sensitivity and motor control in the knee joint was researched.
METHODS: Landing from height, as well as physical loading using the treadmill were applied. The test protocol for the experimental group (n=10) consisted of: 1. testing of the knee joint muscle power (execution of the maximum voluntary contraction, during which the myoelectric signals before fatigue were collected), 2. testing of the knee joint dynamic stability (execution of the tests with two-legged and one-legged landings from the 40 cm high bench during which the kinematic and kinetic parameters were collected), 3. functional fatiguing of the lower extremity musculature (treadmill walking and running with progressive loading until exhaustion, approximately 15-20 min.), 4. identical to phase 1, 5. identical to phase 2. The control group (n=10), on the contrary, has maintained in the 3rd phase the daily level of the physical activity without fatiguing the musculature. First year kinesiology students (freshmen), completely healthy and with motor abilities well developed, participated. Following kinematic variables were studied: valgus and varus angle, angle of inner and outer rotation, as well as angle of flexion and extension in the knee joint (Davis et al., 1991.), as was ground reaction force (GRF). To estimate reproducibility of the biomechanical landing stereotype correlational analysis of the measured signals was used. Raw EMG signals of m. vastus medialis, m. vastus lateralis, m. biceps femoris and m. gastrocnemius were measured during the execution of the maximum static contraction lasting for 10 seconds, with the aid of a dynamometric bench, and used for assessment of the fatigue by spectral analysis. Blod lactate determination was used as a control method to detect fatigue.
RESULTS: The drop in median frequency of the EMG signal power spectrum was noticed in majority of the measured muscles, but statistically significant difference ($p<0.05$) between first and second measurement within the experimental group was found only for the muscles vastus medialis and vastus lateralis. The blood lactate method has confirmed fatigue within the experimental group. Statistically significant decrease of the correlation coefficient value of kinematic parameters, within the experimental group after fatiguing, wass particularly expressed in the inner and outer rotation angle, as well as valgus-varus movement in both knees, pointing to a motor deficit, i.e. a decrease of the proprioceptive sensitivity caused by muscule fatigue. GRF signals have also shown statistically significant differences between groups in almost all components (except the for-aft). It seems therefore that landing does not require excessive efforts in the control of the forces in for-aft direction.
CONCLUSION: A significant influence of fatigue on proprioceptive sensitivity and motor control in the knee joint has been found. Further analysis should include other components of the kinematic chain, including other joints, like ankle. This

method might aid in the prevention of injuries in the rehabilitation phase, when the information of the athlete's susceptibility to increased loading is needed, and also in determining proper timing for involvement into the training process or adequate kinesiological exercise program.

WAVELET SMOOTHING AND SELF-ORGANIZED MAPS IN THE ANALYSIS OF POSTURAL RESPONSES

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AIMS: We have previously shown that the postural adjustments accompanying voluntary leg lifting are different between individuals with and without classical ballet training. However, automatic postural reponses triggered by unexpected surface tilts appear to be less distiguishable between dancers and non-dancers. Comparison based on EMG analysis can be difficult due to inherent system noise and variability in behaviour. Thus, we proposed a new method of analysis based on wavelet smoothing and self-organized maps that enable better classification and detection of synergistic behaviour between groups without any a-priori assumptions.
METHODS: Eleven classically trained ballet dancers and nine controls matched in age, gender and anthropometry were subjected to internally (voluntary leg lifting) and externally (sudden surface tilt) driven balance perturbations. These tasks were performed in multiple directions (front/toes-up, back/toes-down, side/side-up, and combined diagonals) for a set of five trials per direction. EMG responses were recorded from four agonist-antagonist muscle pairs located at the shank, thigh, hip and trunk. Wavelet smoothing was performed on the raw EMG signals using a Daubechies 2(L4) wavelet which demonstrated the highest wavelet intensity contribution to this data set. The filtered data from each individual were then averaged for each condition. The data were then lexiographically stacked such that the data from each subject was strung into a single vector (data points x 8 muscles on the loading limb x 8 muscles on the unloading limb). Data from each subject were placed in a new column in the matrix and principal component analysis was performed. Neural networks using both supervised and unsupervised self-organized maps (SOMs) were applied to the PCA scores. Models was validated using a leave-one-out-cross-validation (LOCV).
RESULTS: EMG SOMs analysis revealed differences between dancers and non-dancers that were not previously detected by more conventional approaches. SOMs could be fitted to the data with little or no error (0-5%) for both balance tasks. These maps illustrated a tighter clustering of muscle activation patterns for dancers during the leg lifting task and non-dancers during surface tilting. Model validation using LOCV showed a dependence on perturbation direction for the robustness of the model. Most directions resulted in 80-100% correct classification. Directions notable for large non-uniformity were backward leg lifting (dancers,67%, non-dancers, 73%) and surface tilts in toes-up (non-dancers,56%), side-up and toes-down (dancers, 55%, 45%) directions.
CONCLUSIONS: Self-organizing maps are useful for the visualization of complex multi-dimensional EMG data in the analysis of motor behaviour and strategies. We believe the distinctions between the groups can explain differences in control strategy. Indeed, the results of this study may be indicitive of increased plasticity within the dancers as is illustrated by the more variable response following unexpected surface perturbation. The comparison of these results with the corresponding kinematic data will further support this idea.

T07.P01
HIERARCHICAL CONTROL OF GOAL-DIRECTED MOVEMENTS

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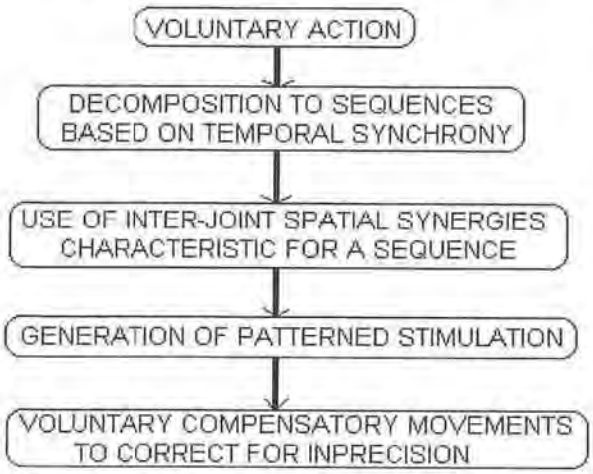
AIMS: The aim is the control method for a neural prosthesis that allows integration of artificial and biological mechanisms during reaching and grasping. The basic assumptions for modeling were the following: 1) control is hierarchical, 2) feedback is used to tune the descending commands, 3) time delays are inevitable; hence, feedback must be combined with the descending commands, and 4) synergies that are being developed through the learning of movement should be mimicked.
METHODS: We studied movements in able-bodied subjects who used various objects that required lateral, palmar, and precision grasps. The objects were positioned far or near a subject, and at various directions with respect to her/his body. Eight angular velocities (abduction/adduction, humeral rotation, shoulder flexion/extension, elbow flexion/extension, pronation/supination, wrist ulnar/radial deviation and flexion/extension, fingers opening/closing, thumb flexion/extension) were used to determine temporal synchronies, that is, the timing of the onset and end of different phases of the movement. Angular accelerations were used to determine spatial synergies, that is, couplings between proximal and distal segments of arm and hand during time windows set by temporal synchronies. Artificial neural network was applied to determine temporal and spatial synergies. The goal was to identify which angular velocities must be used for determining the temporal synergies, and which among eight joint angular accelerations were correlated. The validation was done in data not used for training. The emphasis was on the correlation (>0.9) between the proximal and distal joint trajectories.
RESULTS: The control was simulated. We found that the command signals for driving of distal segments should be the shoulder flexion/extension velocity and acceleration (central descending control), while the feedback needs to include elbow flexion/extension acceleration, wrist radial/ulnar deviation acceleration, and hand opening/closing velocity. The control in addition to the shoulder input I needs the information about the laterality (ipsilateral, in front, contralateral) of the object with respect the body, and type of grasp (lateral, palmar, precision).
CONCLUSIONS: The control tested in 3 tetraplegic individuals proved the concept of the hierarchical synergistic model of reaching and grasping. The next activity is the implementation of this control method for the robot that could be used as a therapeutic tool in neurorehabilitation.



The schema of the hierarchical model of control for goal-directed movements.

T07.P02
THE INFLUENCE OF PACED SOUND IN A FINGER OPPOSITION TASK ON THE ACTIVATION OF SUPPLEMENTARY MOTOR AREA AND CEREBELLUM: A FMRI STUDY

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AIMS: To clarify the influence of external cue (paced sound) on the activation of presupplementary motor area (pre-SMA), supplementary motor area (SMA proper) and cerebellum.
METHODS: We scanned 10 right-handed healthy subjects by functional MRI while they performed (1) self-initiated finger-to-thumb opposition movements every 1 second, and (2) the same movements externally triggered by metronome's sound.
RESULTS and CONCLUSIONS: During self-initiated movements with right hand, right and left SMA proper were significantly activated in 6 and 3 out of 10 subjects respectively. These activations diminished or disappeared in 5 out of 6, 2 out of 3 subjects through paced sound. With left hand, right and left SMA proper were significantly activated in 5 and 1 out of 10 subjects respectively. During externally paced sound, these activations respectively diminished or disappeared in 4 out of 5 and 1 out of 1 subject, however activations of the pre-SMA were little in either hand at self-initiated task. These preliminary results are consistent with previous reports that SMA proper plays more important role especially in the self-paced movements than externally triggered movement. It might explain the paradoxical movements in Parkinson's disease, basal ganglia tightly connects with supplementary motor area. On the other hand, cerebellar activation during the right finger movement with auditory guided methods decreased in seven, vanished in one, and no change was seen in one, out of 9 subjects and during left finger movement with auditory guided methods, the activation decreased in six, vanished in one, out of 9 subjects. Cerebellum acts for feedforward using its internal model. But auditory stimuli might take the place of feedforward function at the cerebellum.

T07.P03
VISUAL EFFECTS ON MUSCLE ACTIVATION OF LOWER LIMB IN YOUNG HEALTHY SUBJECTS DURING DROP LANDINGS

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AIMS: The present study aimed to examine neuromuscular control strategies of the lower limb with different visual conditions and gender during drop landings. Recent research has reported that Electromyographic (EMG) activation was similar in pre-landing phase with vision and no vision and different optical flow. However, little information is available to differentiate muscle activation in the lower limb between different visual flows and gender during impact with the ground.
METHODS: Ten young healthy colleigate volunteers (5 male and 5 female; age 21.3±1.5 year, BMI 21.71±1.5) were recruited. An eight-channel surface electromyograpy system (2000 Hz, Bagnoli™-8, Delsys Inc., USA) and forceplate (2000 Hz,9286AA,

Kistler Instruments Corp., Switzerland) were used to record EMG activity and ground reaction froces during drop landing. Six surface single differential electrodes were used according to the recommendations of SENIAM. Lower limb muscles included for EMG recordings were biceps femoris(BF), rectus femoris (RF), tibialis anterior (TA), gastrocenmius lateralis (GL), peroneus longus (PL) and peroneus brevis (PB) in the subject's dominated leg. Twenty trials of dorp-landing in a randomizrd order were recorded. Subjects performed the landing task from a 40 cm high box in four visual field conditions (no limitation, limited below level, partial limitation and no vision). Data were exported for blinded manual detection of EMG onset. Repeated measures two-way ANOVA were used to determine if there were main effects of vision and gender for muscle activation onset time ($p<0.05$).

RESULTS: There is a trend for delays in onset time of muscle activation with different vision limitation in female subjects. However, no statistically differences were found among four vision conditions ($P>0.05$). Female have significant longer delay onset time ($P<0.05$) in lower limb muscles compared to male subjects (Figure 1).

CONCLUSIONS: Vision flow may play an important role in motor control at drop landings and the results sugges this may depend partly on gender, for young female. Exercise training and rehabiliation program may need to combine visual flows as components for better outcomes.

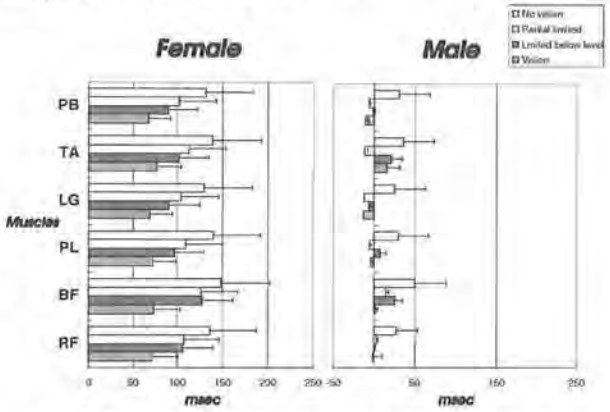
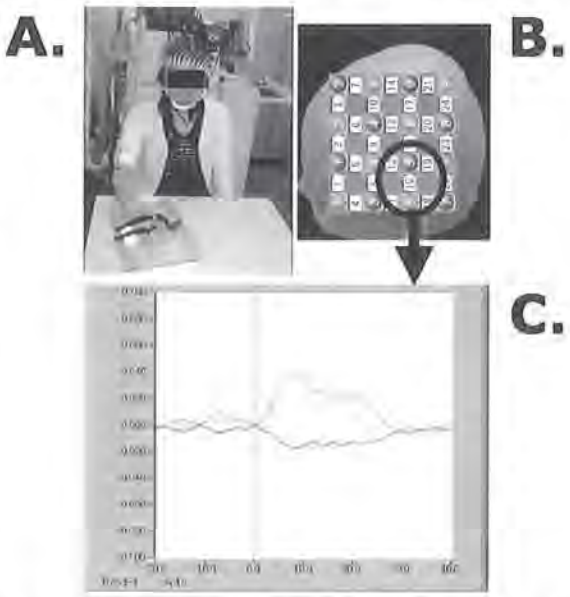


Figure 1: Onset time of lower limb muscles during drop landings.

was kept asking to the subject to touch a ruler set up above of the finger. Five cycles were performed and each of the finger tapping cycles lasted 20 s, followed by a 40 s rest period. Electromyography (EMG) from finger extensor muscle (extensor indicis muscle) was recorded.

RESULTS: All subjects showed activation in motor control area during 100% of ME with maximal EIFT much more than others tasks as well as the EMG showed significant magnitude difference. It's means that tapping with ME with maximal EIFT is directly related to the cerebral activation in motor cortex area.

CONCLUSIONS: These results demonstrated that the rate of change in motor control area at a ME during maximal EIFT task was much higher than that a low frequency EIFT tasks.



A: shows experimental set up. The subjects were instructed to keep the amplitude of movement touching a ruler set up above of the finger. B: the arrangement of optical fibers. Hemodynamic changes of oxi-, deoxi-, and the total- hemoglobin were mensured at 24 regions. C: response to 100% of maximal effort with maximal extension of index finger tapping in channel 15, area related with motor control.

T07.P04
BRAIN STRUCTURES CORRELATES TO FINGER TAPPING USING NEAR INFRARED SPECTROSCOPY

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AIMS: The purpose of this study was clarify the brain related activation area that are involved in six different extension of index finger tapping (EIFT) task using near infrared spectroscopy (NIRS) as well as the relationship between the cerebral activation and the movement frequency.

METHODS: The subjects were laid in a comfortable chair in a semi-darkened shielded room with their eyes closed and instructed to be awake We measured the regional cerebral hemodynamics using 24-channel NIRS to see the changes in oxi-, deoxi-, and the total-hemoglobin from 6 neurologically health subjects under six different EIFT task. These are: 100% of maximal effort (ME) with maximal EIFT, 100% of ME with minimum EIFT, 50% of ME with maximal EIFT, 50% of ME with minimum EIFT, a random EIFT task and only sound task. To determine the frequency at an individual's ME, all subjects underwent the ME trial during maximum amplitude of movement. The subject's index finger was set-up to have the extension movement free and the wrist and the others fingers were immobilized by strap. Each flexion movement of the index finger was accompanied by a beep produced by the equipment and the amplitude of the movement

T07.P05
MUSCLE FIBERS CONDUCTION VELOCITY IS MAINLY AFFECTED BY FORCE INTENSITY THAN CONTRACTION SPEED DURING ISOKINETIC EXERCISE

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AIMS: This study was aimed at investigating the influence of contraction conditions such as speed and contraction force on muscle fibers conduction velocity during non-fatiguing isokinetic exercises.

METHODS: Eight young healthy men participated in the study. The surface electromyographic signals (sEMG) were recorded from the biceps brachii (BB) muscle by means of a 16 silver bar electrodes linear array during three maximal voluntary isometric contractions (MVC) of elbow flexors and a set of three maximal elbow flexions each at 30°, 60°, 120°, 180° and 240°.s^{-1}. Muscle fiber conduction velocity (CV) was estimated from the two double differentials of a triplet of adjacent signals using the EMG cross-correlation (CC) function. Regression line for data sets of torque vs. CV were computed using the least-squares method. Data are presented as mean±SD.

RESULTS: Maximum torque values ranged from 105.37±8.30 Nm at MVC to 61.34±4.39 at 240°.s^{-1}. Maximum CV values

ranged from 5.37±0.13 at MVC to 5.12±0.12 at 240°.s^{-1} (Figure 1). Regression line equation for Torque vs. CV have the form: y=0,0059x + 4,7986 with R^2=0.73.

CONCLUSIONS: During high force contraction such as MVC, large (fast) motor units (MUs) are recruited according to the size principle. Also fast dynamic movement require faster MUs. In this study we observed that CV values increased linearly as torque increased. Since highest forces are exerted at slower velocities, CV seems to be mainly influenced by force than speed of contraction. A possible explanation to this finding is that during fastest dynamic contractions the contribution of fast MUs may not be large enough to increase the CV whilst MUs activated during stronger contractions, with their higher individual firing rates, increase the mean fibers CV.

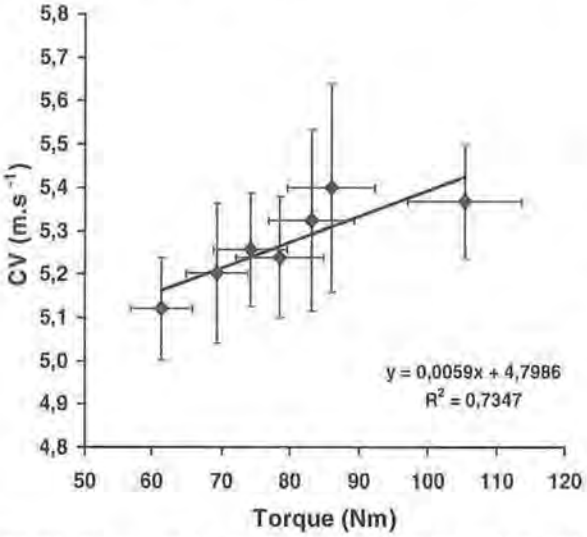

Figure 1: Torque$_{max}$ vs. CV$_{max}$ obtained by subjects during MVC and six contraction speeds. Data are means±SD.

T07.P06
TENNIS PLAYERS SHOW A LOWER COACTIVATION OF THE ELBOW ANTAGONIST MUSCLES DURING ISOKINETIC EXERCISES

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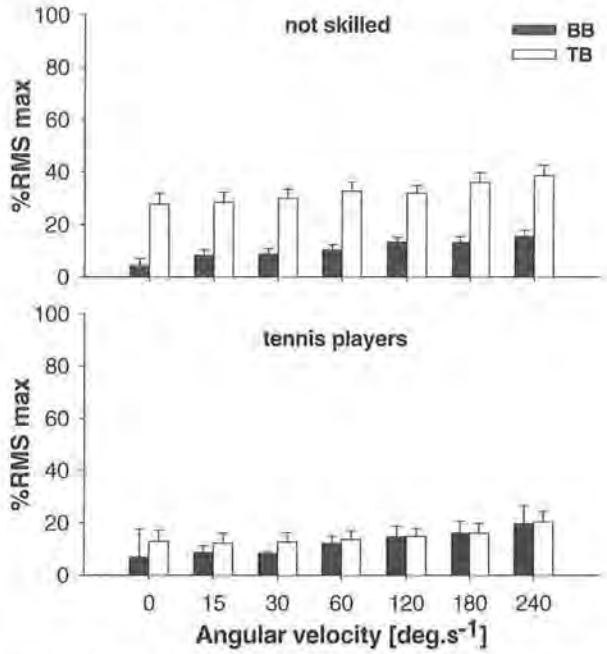
AIMS: The aims of this study were: (1) to verify whether the amount of antagonist activation of biceps brachii (BB) and triceps brachii (TB) muscles is different between not skilled individuals and tennis players and (2) to investigate whether tennis players show any difference in the amount of antagonist activation between BB and TB during isokinetic exercises.

METHODS: Five male tennis players and 10 young healthy men participated in the study. The surface electromyographic signals (sEMG) were recorded from the BB and TB muscles during three maximal voluntary isometric contractions (MVC) of elbow flexors and extensors and a set of three maximal elbow flexions and extensions each at 15°, 30°, 60°, 120°, 180° and 240°s^{-1}. Normalized root mean square (RMS) of sEMG was calculated as an index of sEMG amplitude. A repeated-measures ANOVA was used to assess statistical differences. Data are presented as mean ±SE.

RESULTS: In not skilled subjects torque values ranged from 71.8±9.8 Nm at IMVC to 32.4±4.6 at 240°s^{-1} for EF and from 81.6±7.0 Nm at IMVC to 43.4±4.8 at 240°s^{-1} for EE. Tennis players showed torque values ranging from 86.1 ± 11.6 Nm at IMVC to 50.7±8.0 at 240°s^{-1} for EF and from 80.0±10.5 Nm at IMVC to 42.4±5.2 at 240°s^{-1} for EE. Antagonist %RMS$_{max}$ for BB ranged from 4.4±2.6 at IMVC to 15.5±2.4 at 240°s^{-1} in not skilled subjects and ranged from 6.7±3.1 at IMVC to 19.8±7.1 at 240°s^{-1} in tennis players. TB antagonist %RMS$_{max}$ ranged from 27.7±1.3 at IMVC to 38.7±1.6 at 240°s^{-1} in not skilled subjects and from 12.9±4.3 at IMVC to 20.4±4.0 at 240°s^{-1} in tennis players.

CONCLUSIONS: Contrary to not skilled individuals, tennis players did not show any difference in antagonist activation between BB and TB muscles. Antagonist %RMS$_{max}$ of TB was significantly lower in tennis players with respect to not skilled individuals at all angular velocities. These findings support the hypothesis that a reduced coactivation indicates the achievement of a motor skill (Basmajian J, Arch Phys Med Rehabil 58:38-41,1977). Tennis players, in fact, with a constant practice in controlling forces around the elbow joint, learn how to make use of reactive forces and to reduce the redundant neuromuscular degrees of freedom. This is achieved by the progressive inhibition of muscular activity that is not related to the task.



BB and TB Antagonist %RMS$_{max}$ in not skilled individuals (A) and tennis players (B). Significant difference between muscles (*) and between groups (#).

T07.P07
THE CONTROL OF UPSIDE-DOWN STANDING POSTURE IN SKILLED AND NON-SKILLED SUBJECTS

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AIMS: The purpose of the present study was to monitor the surface electromyographic (sEMG) activity during upside-down standing posture (USP) in skilled (gymnasts) and non-skilled subjects.

METHODS: Six subjects (three gymnasts, three sedentary subjects, mean age: 20.5±1.6 yrs) participated in the study. The sEMG was recorded in a bipolar mode (interelectrode distance: 15mm) from eight muscles on each side during USP exercise performed on a force platform. The USP was maintained for 10 seconds. The muscles investigated were the extensor carpii (EC), triceps brachii (TB), deltoideous (D), trapezius (T), cervical multifidus (CM), gran dorsalis (GD), lumbar multifidus, rectus abdominis. The ground reaction forces exerted during USP on the force platform on the antero-posterior (y), latero-lateral (x), and vertical axes (z) were also recorded; the trajectories of the centre of pression on (x) and (y) axes (COP_x-COP_y) overtime were investigated as well. The sEMG was filtered (cut frequency: 250 Hz), full wave rectified and smoothed with a moving average filter.

RESULTS: The USP was characterized by a tonic EMG activity of all investigated muscles, with the T and D muscles showing the higher EMG activation on average. In all subjects sEMG activity was symmetric, following the same temporal pattern bilaterally. Skilled subjects controlled USP adopting a "wrist strategy" characterized by an EMG activity organized in bursts of the extensor carpii muscles, particularly evident toward the end of USP exercise. This sEMG behaviour was not observed in non-skilled subjects. In no instances, subjects were motionless while hand standing: clear oscillations around the antero-posterior and latero-lateral axes were present. However, these oscillations were 3 to 5 times greater in non skilled than in skilled subjects. The extent of postural instability increased with time, being the oscillations around the latero-lateral axis the more prominent.
CONCLUSIONS: On the basis of this preliminary analysis, it may be concluded that "wrist strategy" is confirmed as the main posture controlling mechanism in gymnasts. Oscillations in the sagittal plane are counteracted by generating appropriate torques around wrist, with other muscles acting synergistically to maintain a fixed body configuration. The differences between skilled and non-skilled subjects points toward an acquired skill, presumably as a consequence of specific training.

T07.P08
STUDY ELECTROMYOGRAPHIC OF MUSCLES DURING THE MANUAL PREHENSION OF DIFFERENTS OBJECTS.

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AIMS: The increasing incidence of muscleskeletal disturbances that affect the distal regions of superior members, constitutes one of the most important public health problems nowadays. A great number of persons presents muscleskeletal pain, reduction of grasping force, directly interfering in hands' functionality. Daily life activities are practical details that constitute a person's day to day tasks. The movements and muscular activity necessary to perform such activities go unnoticed until a wound or sickness interrupts the individual's hability to perform them in a normal way. The rehabilitation expert when meeting a patient with reduced functional capacity, must count on appraisal instruments that give an acceptable degree of objectivity, regarding muscleskeletal structures, to guide in a safe way, the most adequate occupational therapeutic prescription to the patient. This research's objective was to analyse the simultaneous electromyographic activity of extensor carpi radialis longus, flexor carpis ulnaris and 2nd dorsal ulnaris muscles, during objects manipulation in daily life activities.
METHODS: The electromyographic record of the muscles under study was made with 10 healthy volunteers, right handed, 5 women and 5 men, from 25 up to 39 years old. All volunteers signed an agreement term, after explanations about the procedures to be peerformed. The volunteers were kept seated, shrunk shoulders, 90 degrees elbow bending, wrists and hands in neutral position. Movements were then performed according to pre defined protocols. EMG signals during the movement of prehension a cup on the table, taking it to the mouth and then returning to the starting point were recorded. The EMG activity was captured by an *EMG System do Brasil Ltda* composed of differential double electrode, filter at 20-1 kHz, and CMRR of 120 dB, 14-bit A/D converter and sampled at 2 kHz. A differential double electrode was used, with pré-amplification with 100 times pre-amplification, 25 mm^2 contact area and contacts 10 mm apart. Sampling frequency was 2 kHz. All applicable recomendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures. Signal handling consisted in full wave rectification, linear envelope through 4th order Butterworth filter, with 5 Hz frequency of cut, normalized in time base and amplitude, this one through average value. EMG signal's intensity variability was calculated through the variability coefficient (VC). The comparison between the EMG signals from the various muscles was made with the t-test, with significance level of 0.05.
RESULT: The results show that during the cup's grasping movement the extensor carpi radialis longus muscle, responsible for the wrist extension in isolated action and elbow bending in combined action, has greater electric activity when compared to the flexor carpis ulnaris, confirming the results found in literature, while dorsal interossio muscle showed gretaer values than flexor carpis ulnaris, and close to extensor carpi radialis longus muscle, because it performs bending and abduction in relationship to the mean finger during objects' grasping movement.
CONCLUSION: Electromyography is an efficient tool in the study of superior members, and can be used in the clinical appraisal of patients with muscleskelectic lesions, as well as in physiotheraphy, occupational therapy for a better understanding of biomechanical movement.

T07.P09
STUDY OF ELECTROMYOGRAPHIC ACTIVITY OF THE MASSETER MUSCLE IN SLEEP BRUXERS

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AIMS: The electromyography (EMG) has been broadly used as an auxiliary method in the diagnosis of the functional response of the masticatory muscles. The revision of the literature shows that a high EMG activity of the masseter muscle is observed in dysfunctions such as Bruxism. The purpose of this study was to examine the effect of an occlusal splint on masticatory muscle activities in sleep bruxers subjects. Sleep Bruxism usually identified as a parafunction can be defined as unconscious and non-functional activities of the masticatory system muscles.
METHODS: Ten sleep-bruxer subjects with a mean age of 25±5 years participated in this study. Não entendi a seguinte sentença (escreva em português e me passe): the EMG activities of the masseter muscle at both sides were recorded after the use of the occlusal splint in the end of day work activies in the same day without an occlusal splint. The EMG activity was captured by an *EMG System do Brasil Ltda* composed of differential double electrode, bandpass filter at 20 to 1000 Hz, and a subsequent amplification of 50 times with a common mode rejection ratio of 120 dB. The data was sent to a 14-bit A/D converter and sampled at 2000 Hz. A differential double electrode was used, with pré-amplification with 100 times pre-amplification, 25 mm^2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. The recommendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed here. The results were analysed using independent t-test ($p<0.05$).
The electrodes were positioned bilaterally on the masseter muscles. All procedures related to the EMG data followed the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK). The EMG data was analyzed by means of their linear envelopes, obtained after full-wave rectification and low-pass filtering with a 4th order and zero-lag Butterworth filter at 5 Hz. The amplitude of each EMG signal was normalized by the mean valued of the signal. The EMG data were also normalized in time with all data having the same normalized duration. The variability of the intensity of the EMG signal was calculated through the coefficient of variability (CV). The comparison among the signals of EMG of the different studied muscles was made through the t-test for paired samples, and the level of significance adopted was $p=0.05$.
RESULT: In both muscles the maximal EMG activity decreased significantly by wearing the appliance using the splint during in the night when compared with levels muscle activity in the end of day.
CONCLUSION: These findings suggest that nocturnal masticatory muscle activity is significantly reduced by wearing an occlusal splint and that the use of such an appliance at night could help to relax masticatory muscles.

T07.P10
ELECTROMYOGRAPHIC ANALYSIS OF ABDOMINAL MUSCLE IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS

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AIMS: Chronic obstructive pulmonary disease (COPD) is considered an important problem of public health. It is the fourth cause of chronic morbidity and mortality around the world as a global impact pathology, according to the World Health Organization\World Bank. The air inspired and expired from the lungs can be measured with spirometry during slow respiration or during forced expiratory movements, in order to classify the COPD degree. Electromyography is becoming a tool to evaluate the respiratory musculature due to the changes in respiratory mechanics and muscular respiratory weariness, because it is more comfortable to the patient, avoiding bigger overloads to each individual's body, imposed by spirometry. The study's objective was to compare the electromyographic (EMG) activity of right and left superior abdominal muscles in individuals with COPD and in healthy individuals when performing the slow vital capacity movement
METHODS: 20 volunteers of both sexes with 55±10 years old were divided in two groups: A group (Control), individuals with normal spirometric performance, having VEF_1 (forced respiratory flux during the first second) 80% above forecasted; and B group (COPD), individuals with spirometric performance compatible with moderate to severe obstruction, having VEF_1 60% below forecasted. Once identified the two groups, the recording of the electromiographic activity of right and left superior abdominial muscles took place in orthostatic position (upright standing), during the slow vital capacity maneuver (expired gas volume after maximum inspiration, in a slow way). The EMG activity was captured by an *EMG System do Brasil Ltda* composed of differential double electrode, a bandpass filter at 20 to 1000 Hz, and a subsequent amplification of 50 times with a common mode rejection ratio of 120 dB. The data was sent to a 14-bit A/D converter and sampled at 2000 Hz. A differential double electrode was used, with pré-amplification with 100 times pre-amplification, 25 mm^2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. The recommendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed here. The results were analysed using independent t-test ($p<0.05$).
RESULT: No statistically significant difference was observed when comparing the RMS (Root Mean Square) values taken from the right and left superior abdominial muscles of all volunteers from groups A and B, during the slow vital capacity maneuver.
CONCLUSION: The electromyographic records in both groups did not show alterations between groups, since in (COPD) group, the expiration is no longer passive due to the alterations in the respiratory mechanics, making these patients to use actively the abdominal musculature.

T07.P11
STUDY OF INSPIRATORY CAPACITY IN COPD THROUGH SURFACE ELECTROMYOGRAPHY

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AIMS: Chronic obstructive pulmonary disease (COPD) is considered an important problem of public health. It is the fourth cause of chronic morbidity and mortality around the world, specially in the United States, and may reach the fifth position in 2020 as a global impact pathology according to the World Health Organization\World Bank. The air inspired and expired from the lungs can be measured with spirometry during slow respiration or during forced expiratory movements, in order to classify the COPD degree. Electromyography is becoming a tool to evaluate the respiratory musculature due to the changes in respiratory mechanics and muscular respiratory weariness, because it is more comfortable to the patient, avoiding bigger overloads to each individual's body, imposed by spirometry. The study's objective was to evaluate the inspiratory capacity in COPD through surface electromyography of superior and inferior abdominial muscles.
METHODS: 15 volunteers of both sexes with age between 42 to 73 years old were divided in two groups: the control group consisted of individuals with normal spirometric performance, having VEF_1 80% above forecasted. The COPD group consisted of individuals with spirometric performance compatible with moderate to severe obstruction, having VEF_1 60% below forecasted. Once identified the two groups, the recording of the electromyographic activity of superior and inferior abdominial muscles took place, in orthostatic position (upright standing), during the inspiratory capacity. The EMG activity was captured by an *EMG System do Brasil Ltda* composed of differential double electrode, a bandpass filter at 20 to 1000 Hz, and a subsequent amplification of 50 times with a common mode rejection ratio of 120 dB. The data was sent to a 14-bit A/D converter and sampled at 2000 Hz. A differential double electrode was used, with pre-amplification with 100 times pre-amplification, 25 mm2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. The recommendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed here. The results were analysed using independent t-test ($p<0.05$).
RESULT: No statistically significant difference was observed when comparing the RMS (Root Mean Square) values taken for the superior and inferior abdominial muscles of all volunteers from groups A and B, during the inspiratory capacity.
CONCLUSION: The electromyographic records in both groups did not show alterations between groups during inspiratory capacity, since in the CPOD group, the expiration is no longer passive due to the alterations in the respiratory mechanics, resulting in a paradoxal respiration which makes the patients use actively the abdominal musculature.

T07.P12
EVALUATION OF ELECTROMYOGRAPHIC ACTIVITIES OF MASSETER AND TEMPORAL MUSCLES IN INDIVIDUALS WITH TEMPOROMANDIBULAR DISFUNCTION

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AIMS: Electromyography (EMG) has been widely used as a method to help the diagnosis of temporomandibular disfunctions (TMD) and to evaluate the functional behaviour of mastigation muscles at idle state and during jobs' execution, as mastigation or tightening in some levels. The literature's revision shows the existence of a correlation between the electromyographic activity of anterior masseter and temporal muscles and the oclusion in patients with TMD. This study's objective was to evaluate the changes in electromyographic activity of anterior masseter and temporal muscles, before and after seven days of utilization of a modified Hawley device, linking these alterations with TMD's signals and symptoms and this way to verify the clinical effectiveness of this device
METHODS: Twenty female patients, 25±5 years old, showing spontaneous pain in the region of mastigation muscles or in temporomandibular articulation (TMA). Modified Hawley device:

a palatal device made with acrylic resin, with circular holders adapted to the last teeth present in the superior arc and a vestibular front in the lip's portion of the anterior teeth with an anterior platform, for the contact in centric relationship with the antero-inferior teeth. Patient's electromyographic measurements were made at rest and at maximum voluntary contraction The EMG activity was captured by an *EMG System do Brasil Ltda* composed of differential double electrode, bandpass filter at 20 to 1000 Hz, and a subsequent amplification of 50 times with a common mode rejection ratio of 120 dB. The data was sent to a 14-bit A/D converter and sampled at 2000 Hz. A differential double electrode was used, with pre-amplification with 100 times pre-amplification, 25 mm^2 contact area and contacts 10 mm apart. Sampling frequency was 2000 Hz. All applicable recomendations from the International Society of Electrophysiology and Kinesiology (ISEK) regarding electromyography's applications were followed in all EMG signal's procedures. Signal handling consisted in full wave rectification, linear envelope through 4^{th} order Butterworth filter, with 5 Hz frequency of cut, normalized in time base and amplitude, this one through average value. EMG signal's intensity variability was calculated through the variability coefficient (VC). The comparison between the EMG signals from the various muscles was made with the t-test, with significance level of 0.05.

RESULT: The electromyographic signals before and after the seven days period showed a tendency for increase in the muscular activity, at rest as well as at maximum contraction, without statistically significant differences. Clinical evaluation showed an improvement in the patients' symptoms after the palatal device's use.

CONCLUSION: The above results suggest that the palatal device's use can bring improvements for patients with temporomandibular disfunction, being necessary to increase the number of observations and follow up time in each case.

T07.P13
AMOUNT OF RECIPROCAL IA INHIBITION IN ISOKINETICS MOVEMENT

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AIMS: Reciprocal Ia inhibition between ankle flexor and extensors in mammalia has been studied at rest or during joint action. However previous literatures have not clarified the variations in this inhibition at movement switching speed. The purpose of this present study is to elucidate the relationship between variations of reciprocal Ia inhibition and the speed stage of isokinetics movement.

METHODS: Experiments were performed on eight normal volunteers, all of whom have given informed consent to the procedure. All of subjects were asked to move the ankle by the isokinetics machine quickly. The angle velocity was set to 60, 90 and 120 deg/sec, the device was fixed planter flexion zero degree. The measurements of soleus H-reflex were carried out when the ankle joint changed from plantar flexion to dorsiflexion at 0 degree instantaneously. A test H-reflex was evoked by electrical stimulation of the tibial nerve, and the conditioned stimulus was given to the common fibular nerve. The effects of reciprocal Ia inhibition were calculated as percentage of test H-reflex amplitude to the control H-reflex at rest. The inhibition was analyzed using repeated measure by ANOVA. Thukey-Kramer post hoc test was used to determine the differences between the control (at rest), conditioning-test (CT) interval 0ms, 1ms, 2ms, and 3ms respectively. The probability values less than 0.05 were contemplated significantly.

RESULTS: The inhibition were 90.7±0.1, 108.0±0.3, 113.2±0.4, 106.4±0.4 at the control, 60 deg, 90deg, and 120deg mutually on CT interval 0ms. There was no significant difference between each group. The inhibition were 77.7±0.1, 118.0±0.6, 107.6±0.2, 118.4±0.4 at the control, 60 deg, 90deg, and 120deg mutually on CT interval 1ms. There was a significant difference respectively for the control and 60 deg ($p<0.05$), and for the control and 120 deg ($p<0.05$). The inhibition were 73.6±0.2, 119.6±0.5, 116.6±0.5, 118.6±0.4 at the control, 60 deg, 90deg, and 120deg mutually on CT interval 2 ms. There were significant differences respectively for the control and other groups ($p<0.05$). The inhibition were 71.6±0.3, 120.9±0.4, 115.8±0.4, 123.2±0.5 at the control, 60 deg, 90deg, and 120deg mutually on CT interval 3 ms. There were significant differences respectively for the control and other groups ($p<0.05$).

CONCLUSIONS: The H-reflex amplitude (% of control) have facilitated when ankle pumping increased though the effects of reciprocal Ia inhibition have seen at rest. It is known that the soleus H-reflex is decline when ankle extensor contractions increase. As above mentioned, we think there might be possibility that reciprocal Ia inhibition has performed before the ankle joint changed from plantar flexion to dorsiflexion at 0 degree rather than the inhibition has not disappeared while faster ankle pumping. It is thought that a volley from CNS influence more than spinal segment. For example, there might be possibility that the pattern generator of midbrain influences.

T07.P14
MODULATION OF SOLEUS H-REFLEX AND SPINAL INHIBITORY CONTROL SYSTEMS DURING IMPOSED SINUSOIDAL HIP MOVEMENTS IN HUMAN SPINAL CORD INJURY

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AIMS: The aim of this study was to establish the modulation pattern of the soleus H-reflex during imposed sinusoidal hip movements in seven motor and sensory incomplete spinal cord injured (sci) subjects when administered alone and following excitation of group I antagonistic muscle afferents.

METHODS: All procedures were conducted according to the 1965 declaration of Helsinki and all subjects consented prior to testing. The right hip joint was subjected to sinusoidal movements at 1.2 rad/sec while subjects were lying supine (Fig. 1a). EMG potentials of five leg muscles and joint torques were also recorded. Soleus H-reflexes recorded alone or conditioned by common peroneal nerve stimulation at either short (2, 3, 4 ms) or long (80, 100, 120 ms) conditioning test intervals (associated with reciprocal ia and presynaptic inhibition respectively) during imposed hip flexion and extension were elicited and recorded via conventional methods.

RESULTS: Sinusoidal hip movements induced a similar modulation pattern to the soleus H-reflex, compared to the one previously reported during imposed static hip angle changes. The soleus H-reflex was significantly depressed during hip flexion and it was facilitated during hip extension (Fig. 1b & c), while pre-stimulus soleus EMG activity did not contribute to the reflex modulation. Further, a hip movement-dependent modulation of actions from the antagonistic muscle afferents was present, with reciprocal and presynaptic inhibition to be reduced during dynamic hip extension and to be reinforced during hip flexion.

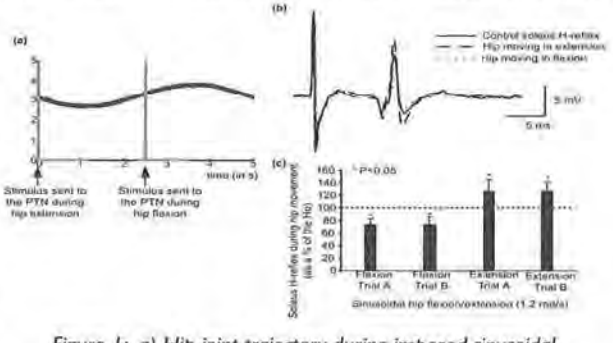

Figure 1: a) Hip joint trajectory during imposed sinusoidal movement. Timing for soleus H-reflex elicitation is indicated. b) Waveform averages of soleus H-reflex during imposed hip movements and under control conditions. c) Pool data of soleus H-reflex amplitude during dynamic hip flexion and extension.

EMG activity of thigh and lower leg muscles were generally seen to be entrained to the hip movement. Hip and knee joint torques displayed a complex behavior.
CONCLUSIONS: Our current findings suggest that hip proprioceptive cues modulate the soleus H-reflex regardless of the nature of the movement, i.e. static or dynamic. Further, under dynamic conditions hip proprioceptors interact with distal muscle afferents to modulate the amount of inhibition exerted on soleus Ia afferents or on soleus alpha motoneurones. Actions of these interneuronal circuits may be related to the functional recovery of walking in sci patients.

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T07.P15
CORTICOSPINAL EXCITABILITY CHANGES DURING LENGTHENING BUT NOT SHORTENING CONTRACTIONS AFTER TRAINING

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AIMS: Lengthening (LEN) and shortening (SHO) contractions are the fundamental patterns of muscle activation underlying most movements. Enoka (1996) put forward that the neural commands controlling LEN are unique, but the distinct neural mechanisms still remain unclear. We have investigated the corticospinal excitability during LEN and SHO by using transcranial magnetic stimulation (TMS). The corticospinal excitability can be characterized by an input-output (I/O) curve. This I/O curve usually displays a sigmoidal shape, and is further characterized by the plateau value, maximum slope, and threshold. In both the elbow flexors and the soleus muscle, we reported that the plateau value and maximum slope during LEN were significantly lower than those during SHO (Sekiguchi et al. 2001, 2003). These findings would indicate that the gain of the corticospinal pathway is lower during LEN than during SHO. In a pilot study, however, we found that the modulation of corticospinal excitability in the first dorsal interosseus muscle (FDI) was different from that in previously tested muscles. Namely, the maximum slope and threshold in the FDI were higher during LEN than during SHO, whereas the plateau value was a similar level. The purpose of this study was, therefore, to investigate whether or not the characteristics of the I/O curve approximate those in our previous reports after training consisting of LEN and SHO in the FDI.
METHODS: Sixteen subjects were randomly assigned to one of two groups, the "training group" and the "control group". Subjects performed abduction/adduction movements (8°/s) of the index finger through a 20° range of motion. Parameters of the I/O curve and the silent period were compared before and after 2-weeks of training. Training consisted of 10 sets of 12 repetitions performed 3 x week, with each repetition consisting of movements over the entire range of motion in the abduction-adduction plane (~40°) with a light load (5% MVC). Fluctuations in position (SD) was used to quantify performance. Additionally, in 2 more participants, transcranial electrical stimulation (TES) was applied before and after the training to investigate a gain change at the subcortical level.
RESULTS: The performance in SHO and LEN improved with two weeks of training ($P<0.05$) and this was accompanied by a reduction in the maximum slope during LEN only ($P<0.01$). Furthermore, there was a strong correlation in the rate of change between performance and the maximum slope during LEN in the training group ($r=0.813$, $P<0.05$). Before training, the duration of silent period elicited by TMS was significantly longer during LEN than that during SHO. After training, the silent period during LEN was reduced to similar durations as SHO. The gain, which is indicated by the regression line through the relation between electrical stimulus intensity and MEP area, was also reduced with training in LEN, whereas there were no changes in SHO.
CONCLUSIONS: The present results show that the modulation of corticospinal excitability in the FDI after training came partly close to that in our previous reports. To perform the lengthening contractions precisely, a reduction in gain is necessary. Furthermore, the results for the silent period data and the TES sessions indicate that the reduced gain of corticospinal excitability likely occurs at the spinal level.

T07.P16
CORTICAL REGULATION OF ISOMETRIC FORCE - CORTICOMUSCULAR COHERENCE ANALYSIS -

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AIMS: Relationship between electromyogram (EMG) and muscle's force-output patterns has been well studied so far, but how the sensorymotor cortex tunes muscle's force output is still unclear. In order to understand the feedforward mechanism from the cortical activity to force production through spinal motoneuronal behavior, we developed a new signal-processing method of corticomuscular coherence analysis. To valid this technique, we analyzed both simulated and experimental data in this study.
METHODS: We recruited a total of 15 healthy subjects, who gave the informed consent. The following procedure approved by the local ethics committee was exermined. Elecroencephalogram (EEG) were recorded from the vertex, where the sensorymotor cortex was located nearby. EMG was also recorded from the right tibialis anterior (TA) muscle. The subjects dorsiflexed tonically with 30% of maximum voluntary contraction (% MVC) in 80 seconds. Isometric force was measured using a strain gauge implemented to the ankle-foot arthosis. The coherent frequency component of EMG to EEG was identified by corticomuscular coherence analysis, and the envelop of its coherent signal in EMG was extracted by a specific signal filter, newly proposed in this study. Coherence between the envelope of EMG and the force signal was verified by coherence analysis.
RESULTS: EMG bursted continuously in coherence with EEG's beta (15-30 Hz) band. The envelope of this burst activity was oscillated around 1-2 Hz. The force-ouput oscillated around 1-2 Hz in coherence with the envelope of the EMG burst, and rippled in 15-30 Hz phase-lockingly to each peak of EMG burst.

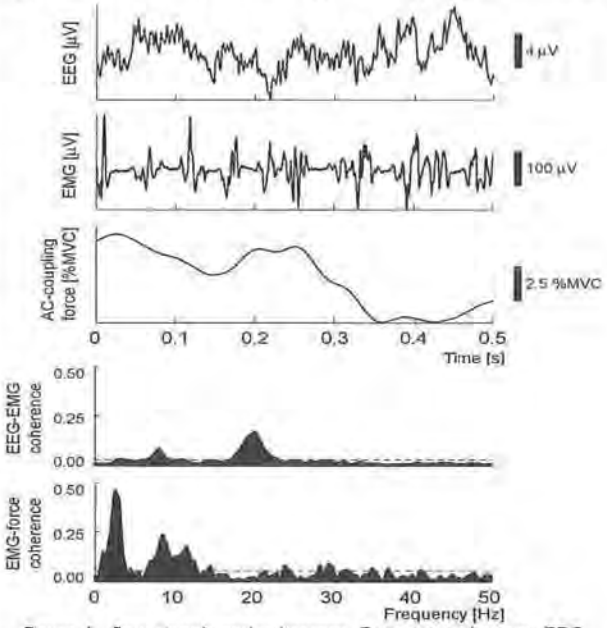

Figure 1. Raw signals and coherence. From top to bottom: EEG from Cz, TA's EMG, force produced, EEG-EMG coherence, and EMG-force coherence calculated using the newly developed method. Dotted lines show the significant level (α=5%).

Such experimentally observed biosignal configuration was expressed as mathematical equation, and the newly developed method was applied to both simulated and experimental data. The conventional coherence method quantified the burst frequency itself (15-30 Hz), and the newly developed method evaluated the envelope frequency of the burst wave (1-2 Hz), which tunes the muscle's force production (Fig. 1).
CONCLUSIONS: Experimental observation suggested that the cortical drive is regarded as AM (amplitude modulation) signal. The cortical drive to the spinal motoneuron oscillated in 15-30 Hz, and its amplitude modulation of which frequency was 1-2 Hz determined the actual force level. Therefore, it could be said that the method of corticomuscular coherence analyzes frequency contents of the carrier wave of the cortical drive, and the newly proposed signal-processing for corticomuscular coherence analysis extracted frequency contents of the modulation wave on the cortical drive, which tunes muscle's force fluctuation. More details for physiological application of this analytical method will be also presented in our other posters.

T07.P17
A SIMPLE VALIDATION OF CO-CONTRACTION INDICES

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AIMS: Co-contraction (the simultaneous activation of antagonist muscles around a joint) during human movement is often described using a variety of co-contraction indices (CCI), which apparently none of them have been validated. The goal of this work was to perform a simple validation of different CCI reported in the literature. The following CCI were investigated: the ratio between the antagonist muscles electromyography (EMG) amplitudes non-normalized (CCI1); normalized by their maximum voluntary isometric (MVI) contraction values (CCI2); and normalized by their MVI co-contraction values (CCI3). The effect of muscle pain on the muscle contraction and co-contraction was also investigated.
METHODS: Ten healthy adults performed tasks involving isometric contractions and co-contractions with the biceps and triceps brachii. First, the biceps MVI contraction was determined and then the visual feedback of the biceps EMG amplitude was given to the subjects and they performed isometric co-contractions (a theoretical co-contraction of 100%) at four different contraction levels: 25, 50, 75 and 100% of the biceps MVI contraction. In addition to performing these tasks in a normal condition, the subjects also performed these tasks with experimentally induced muscle pain, induced by injecting 1.0 ml of hypertonic saline (5.8%) into the biceps brachii muscle. The different CCI described above were computed for the co-contractions at different contraction levels and compared to the true co-contraction value of 100%.
RESULTS: The CCI that reached the closest value to 100% was the CCI3 with a mean value of 84±4%. For CCI1 and CCI2 the mean values were 77±6% and 70±6%, respectively. During the condition with muscle pain, the MVI contraction force decreased in relation to the normal condition but the CCI were not affected by the factor muscle pain.
CONCLUSIONS: The CCI that normalizes the EMG amplitude by the MVI co-contraction values seems to be the most accurate. Experimentally induced muscle pain does not affect CCI in various muscle contraction levels.

T07.P18
DIFFERENTS PATTERNS OF RECRUITMENT IN ECCENTRIC AND CONCENTRIC CONTRACTIONS IN MULTIFIDUS LUMBORUM DURING FLEXION-RELAXATION TEST

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AIMS: Different patterns of recruitment in motor units during eccentric and concentric contractions in limb muscles has been documented. However, this phenomenon has not been deeply studied in paraspinal muscles. These patterns of recruitment are critical for spinal stability and ensure the normal functioning of the lumbar spine. Thus, the purpose of this study was to assess and define such patterns of recruitment in multifidus lumborum during eccentric and concentric contractions in the flexion-relaxation test.
METHODS: Surface EMG from multifidus lumborum muscle (n=40) was acquired during the execution of flexion-relaxation test. Kinematic data of anterior trunk inclination and lumbar flexion were collected simultaneously with EMG activity. A visual and auditive feedback was provided to each subject for controlling the phases of the test (flexion, relaxation, and extension). In order to evaluate the patterns of recruitment of multifidus lumborum for each contraction, a window of one second whose middle point coincided with 45 degrees of trunk inclination, for both eccentric and concentric burst was used. A discrete wavelet transform (DWT) using daubechies order 8 was used for each burst to transform each burst to time-frequency domain. A DWT matrix showed the spectral components existing in a discrete space of time. After that a mean matrix and the intensity (RMS) in every box of wavelet coefficients series was calculated.
RESULTS: The morphology of EMGs signal for both contractions was different. Eccentric contractions were characterizated by an intermitent activation with a significant increase in the intensity of frequencies band of 8-16 Hz (p=0.0006) and 16-32 Hz (p=0.0002) while concentric contractions had more intensity at

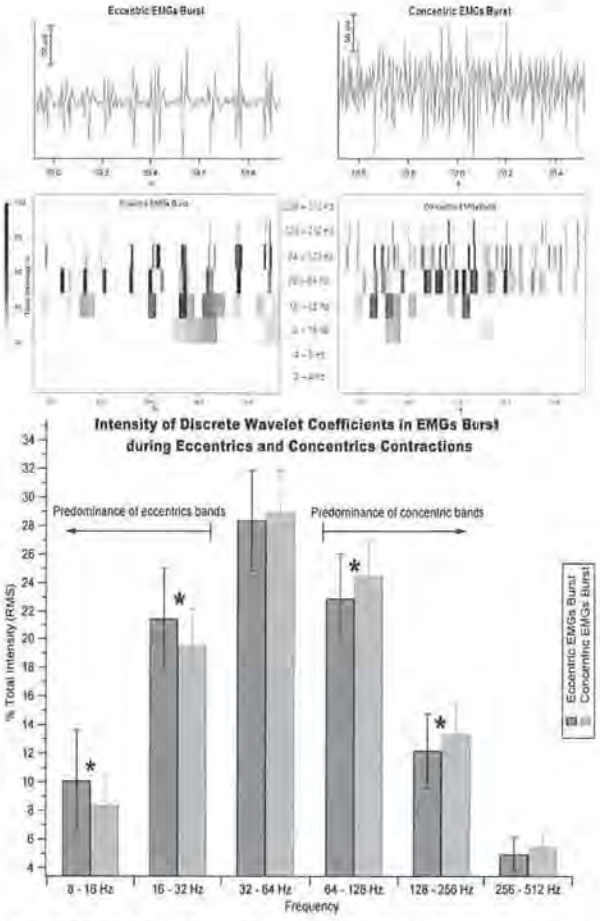

Figure shows the EMGs signals, discrete wavelet transform matrix and intensity coefficients wavelets for both types of contractions.

64 Hz and higher frequencies (p=0.001 and p=0.0007, respectively). Both contractions showed the higher intensity of frequency in the 32-64 Hz band (p=0.439). No differences were found in this range of frequency between both contractions.
CONCLUSIONS: Discrete wavelet coefficients between 32 to 64 are common and exhibit the greater intensity in both concentric and eccentric contractions. Nevertheless, low frequencies coefficients such as 8-16 Hz and 16-32 Hz predominated in eccentric contractions; while higher frequencies coefficients such as 64-128 and 128-256 predominated in concentric contractions. These results showed that an unusual intermitent recruitment of muscle fibres in eccentric contraction exists. An enhanced syncronization, a lower mean discharge frequency and more variable pattern of firing of motor units in limbs in eccentric contractions have been demonstrated. These findings are in line with our findings. Multifidus muscle showed different patterns of recruitment with different contractions. This could be used as strategy to execute a task and ensure a normal functioning of the spine.

T07.P19
NEURONAL CONTROL OF UPRIGHT POSTURE ON ROCKING-PLATFORM

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AIMS: Human upright posture is often modeled as an inverted pendulum, and has been analyzed in terms of kinematics. Neuronal mechanism for maintaining upright posture is, however, less known so far. Therefore in this study, we investigated motor control mechanism of sensorimotor cortex for maintaining upright posture by means of corticomuscular coherence analysis.
METHODS: Electromyogram (EMG) was recorded from the tibialis anterior (TA) and soleus muscles with surface bipolar electrodes. Electroencephalogram (EEG) was obtained from 13 electrodes placed around the vertex. A rocking-platform, a semicircle pillar of a radius of 200 millimeters, was lain on the force plate. In this situation, the sway of the rocking-platform was restricted in the anterior-posterior directions, and was measured as the center-of-pressure (COP). Ten young healthy subjects were recruited and each subject kept upright posture on the rocking-platform for 100 s. We used coherence analysis and phase spectra analysis to EEG, EMG, and the COP signals in order to determine the neuronal signal flow related to posture control.
RESULTS: EEG-EMG coherence showed three significant peaks in 4, 10, and 30-40 Hz ranges (Fig. 1(a)). According to the result of phase-spectra analysis, the signal of 30-40 Hz was conveyed from the sensorimotor cortex to the muscle. On the other hand, the signals of both 4 and 10 Hz ranges were conveyed from the muscle to the sensorimotor cortex (Fig. 1(b)). In EMG-COP coherence analysis, EMG and COP signals were coherent in 4 Hz range.
CONCLUSIONS: The efferent signal in 30-40 Hz can be regarded as the motor command from the sensorimotor cortex, and the motoneuron pool rhythmically discharges in 10 Hz by 3 to 1 response on the motor command. In addition, the information of such muscle activity is conveyed sensorimotor cortex via the sensory pathway. Also, the rocking-platform had swayed in 4 Hz. Judging from that, we suppose that stretch of the ankle by such sway causes EMG, and that the information of the sway which the muscles felt is conveyed to sensorimotor cortex as the afferent signal.
Although coherence analysis quantified the nervous system macroscopically, our study may suggest that neuronal regulation for maintaining upright posture can be analyzed in addition to kinematic approach.

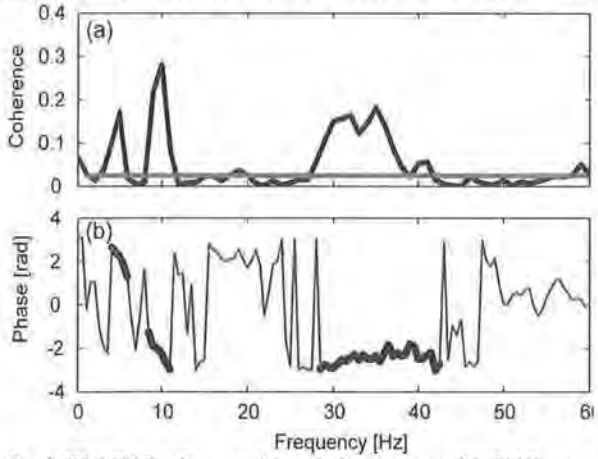

Fig. 1. EEG-EMG coherence (a) and phase spectra (b). EMG was obtained from TA. The gray horizontal line in the coherence spectra indicates the 95% confidence limit (a). Phase estimates within the significantly coherent range are shown as a black line. The slopes of the phase spectra show the direction of the signal flow (b).

T07.P20
ANGLE- AND VELOCITY-SPECIFIC ALTERATIONS IN TORQUE AND SEMG ACTIVITY OF THE QUADRICEPS AND HAMSTRINGS DURING ISOKINETIC EXTENSION-FLEXION MOVEMENTS

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AIMS: The purpose of this study was to investigate the effect of movement velocity (100°, 200°, 300°s^{-1}, and 400°s^{-1}) and joint position (0°-15° [L0], 25°-40° [L25], 55°-70° [L55], and 75°-90° [L75]) on peak torque (PT) parameters and surface electromyography (SEMG) of the knee-joint muscles during reciprocal isokinetic extension and flexion movements.
METHODS: Thirteen subjects (age=22.7±2.1 years, mean height =161.1±6.6 cm, mean weight=63.5±5.8 kg) participated in the study. Bipolar surface electrodes were placed over the vastus medialis, vastus lateralis, biceps femoris, and medial hamstrings for determination of the root mean square ($SEMG_{rms}$) and median frequency ($SEMG_{mf}$) of the SEMG. Peak torque, angle of peak torque (PT_{ang}), percentage of peak torque (PT_{per}), $SEMG_{rms}$, and $SEMG_{mf}$ were analyzed using separate repeated measures analysis of variance (ANOVA).
RESULTS: The following main results, significant at $p \leq 0.05$ or better, were found: the PT_{ang} was influenced by movement velocity (in extension there was a decrease in PT_{ang} moving from 300°.s^{-1} to 400°.s^{-1} and in flexion there was an increase in PT_{ang} moving from 300°.s^{-1} to 400°.s^{-1}). Secondly, a greater percentage of peak torque (PT_{per}) was maintained during knee flexion than knee extension. And thirdly, both the quadriceps and hamstrings exhibited changing amplitudes and spectral frequencies based on joint position and movement velocity. There was a trend of decreasing $SEMG_{rms}$ for the quadriceps as the knee moved into extension, and a lower $SEMG_{mf}$ during early (L75) and end stages of knee extension (L0). For the hamstrings, $SEMG_{rms}$ was lowest at the more shortened position (L75) and highest near the mid-position (L25); the lowest $SEMG_{mf}$ occurred at the more lengthened position (L0) and the highest occurred at the more shortened position (L75). Finally, velocity influenced hamstrings and quadriceps muscle amplitude such that $SEMG_{rms}$ was highest at the slower velocities and lowest at the higher velocities. Velocity had no impact on quadriceps spectral properties ($p>0.05$), but had a cyclic effect on hamstrings spectral properties.
CONCLUSIONS: Changes in amplitude and frequency spectrum in tested muscles could be explained, in part, by neural drive to these muscles. Our data support the hypothesis of lower activation levels of the quadriceps muscle in the extended position espoused by several authors as a way to protect the knee-joint in the knee-extended position.

T07.P21
EVALUATION OF THE ADDUCTOR POLLICIS MUSCLE OF ELDERLY PATIENTS USING A MODIFIED HANDLE OF TOOTHBRUSH

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AIMS: The aim of this study was to evaluate the muscular activity of the adductor pollicis muscle, by electromyography, when using a device made of acrylic resin adapted to the handle of toothbrush.
METHODS: 10 patients of boths gender from the Clinic of Removable Partial Prosthesis of the Dentistry School - USP, with a mean age of 65 years, were selected. Electromyographic records were obtained with patients in clinical conditions of Initial Rest and under conditions of claw apprehension and dental brushing.
RESULTS: The mean results obtained, in μV, were: sat men: 2.97 for rest (R); 11.55 for free closure (FC); 35.80 for strained closure (SC); 29.30 for simulated brushing (SB); 55.00 for brushing (B); 26.87 for simulated brushing with the device (SBA); 69.70 for brushing with the device (BA); 3.72 for postexercise rest (PR). Standing: 2.27 for rest (R); 13.92 for free closure (FC); 45.85 for strained closure (SC); 28.40 for simulated brushing (SB); 72.07 for brushing with the device (BA); 1.42 for postexercise rest (PR). Sat women: 9.78 for rest (R); 22.71 for free closure (FC); 41.48 for strained closure (SC); 26.45 for simulated brushing (SB); 52.78 for brushing (B); 17.00 for simulated brushing with the adapter (SBA); 42.38 for brushing with the adapter (BA); 14.40 for postexercise rest (PR). Standing: 5.26 for rest (R); 17.81 for free closure (FC); 46.55 for strained closure (SC); 40.61 for simulated brushing (SB); 61.71 for brushing (B); 26.08 for simulated brushing with the adapter (SBA); 54.06 for brushing with the adapter (BA); 3.46 for postexercise rest (PR).
CONCLUSIONS: The adductor pollicis muscle showed a higher electromyographic activity, considered statistically similar to each other, in 3 clinical conditions analyzed: B, BA and SC and lower electromyographic activity, considered statistically similar, in 5 clinical conditions analyzed: simulated brushing (SB), simulated brushing with the adapter (SBA), free closure (FC), R and post exercise rest (PR).

T07.P22
ROLE OF BOTH INTERACTION TORQUE AND MUSCLE TORQUE IN SQUATTING

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AIMS: The contribution of interaction torque to net torque in multi-joint movement is unexpectedly large, as the control of muscle torque is not considered without interaction torque. However, the role of interaction torque in the whole-body movement of the squat motion have not yet been examined. The purpose of this study was to examine the contribution of both interaction torque and muscle torque to net torque in squatting.
METHODS: Subjects were 5 healthy men with a mean age of 22.4±0.9 years, mean height of 174.2±2.9 cm, and mean weight of 73.1±12.7 kg. Markers were placed on both sides of the tip of acromion process, great trochanter, lateral femoral epicondyle and lateral malleolus of the subject. All subjects performed squatting from 10-60 of knee flexion at a neutral standing position after sufficient practice. Subjects were also asked to move "as fast as you can after the auditory cue signal". All squatting movements were recorded at a sampling frequency of 50 Hz (ELITE Plus, BTS). Marker positions were used to calculate joint angles, then net torque, interaction torque, muscle torque and gravity torque according to a Lagrange equation of a 3-segment model using a mid-point on both sides of each marker. Moreover, electromyography (TELEMG, BTS) was recorded from 8 parts of 7 muscles on the right side during squatting: gluteus maximus; rectus femoris; biceps femoris; vastus medialis; tibialis anterior; soleus, and the medial and lateral heads of gastrocnemius. Sampling frequency was 1 kHz. Root-mean-square (RMS) value was calculated with electromyographic signals for 75-ms windows. Each subject provided written, informed consent to participate.
RESULTS: Maximum acceleration value of the center of gravity downward was 6.3±1.3 ms^{-2}. Both net torque and interaction torque displayed two-phase, then muscle torque displayed either 2 or 3 phases. Peak net torque was 165.1±56.2 Nm at hip flexion, 720.9±173.0 Nm at knee flexion and 759.4±199.6 Nm at ankle dorsiflexion. Peak interaction torque was 141.8±41.7 Nm at hip flexion, 691.5±168.1 Nm at knee flexion and 752.2±191.8 Nm at ankle dorsiflexion, then the interaction torque wave synchronized with net torque wave. Moreover, peak muscle torque was 29.6±19.2 Nm at hip flexion, 14.6±14.2 Nm at knee flexion and 14.9±19.6 Nm at ankle dorsiflexion. Although peak muscle torque of knee-flexion appeared earlier than the peaks of either net torque or interaction torque, peak muscle torque for both hip flexion and ankle dorsiflexion appeared late. Conversely, activity of gastrocnemius increased the earliest, then tibialis anterior, soleus and gastrocnemius contracted simultaneously.
CONCLUSIONS: The contribution of interaction torque to net torque was very large, and adjusting the difference between net torque and interaction torque is the role of muscle torque. Moreover, the ankle joint is controlled by co-contraction of tibialis anterior, soleus and gastrocnemius, and this seems to increase stability of the ankle joint.

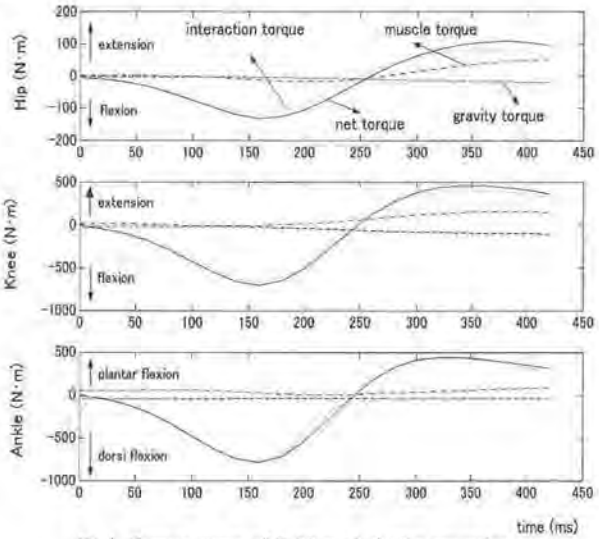

Fig. 1. Torque curve of Subject A during squatting.

T07.P23
CHANGES OF CORTICOMUSCULAR COHERENCE DURING MUSCLE FATIGUE

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AIMS: Generally it is known that the amplitude of the surface electromyogram (EMG) increases during muscle fatigue, and the frequency shifts to the low frequency region. Tremulous movement thus may be considered to be induced. However, the signal source of such large-amplitude and low-frequency rhythmic activity of EMG is yet to be clear. Therefore we examined that the corticomusclular drive is enhanced during muscle fatigue by means of functional coupling between electroencephalogram (EEG) and EMG.
METHODS: Subjects were six right-handed normal males aged from 22 to 25 years (mean 22.8 years). EMG was recorded from the tibialis anterior muscle of the right leg. EEG was recorded

from the vertex. The experimental procedure consisted of three parts. In the first part, as a control task, recordings were made over period of 10 seconds. The subjects were instructed to keep tonic dorsiflexion with 30% of maximum voluntary contraction (MVC). We recorded a total of 12 periods with adequate rests of at least 15 seconds for each period. After a rest period of 60 seconds, the subjects were instructed to keep 50% of MVC, as long as they could (185 seconds in average), to induce muscle fatigue (part 2). Soon after, the subjects were again instructed to keep 30% of MVC over period of 60 seconds in order to compare with the control task (part 3).

RESULTS: A typical example of EEG and EMG is shown in Fig.1. The EMG pattern of the fatigued muscle was obviously different from the normal one, although the strength was not changed. EMG of fatigued muscle bursted rhythmically (about 20Hz; Fig.1 B), and the strength of coherence was increased. This trend was observed in all six subjects, regardless of the ordinary strength of coherence in non-fatigue condition.

DISCUSSIONS: Strength of corticomuscular coherence is increased by muscle fatigue. We considered that the motor drive descended from the sensorimotor cortex becomes more synchronously to make burst activity of the spinal motoneuron pool for the compensation of the decrease of force production per motor-unit twitch due to muscle fatigue.

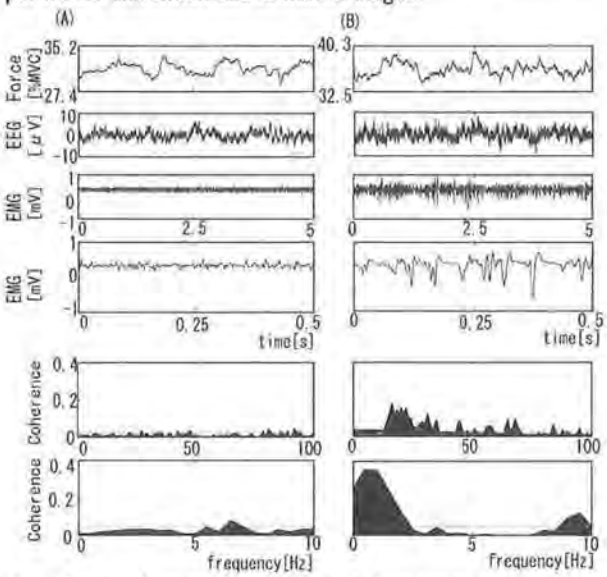

Fig.1: Signals of two conditions. For each, from top to bottom force, EEG, EMG, EMG (zoom up), EEG/EMG coherence and EMG/force coherence. 95% confidence level is indicated as the dotted lines. (A) control and (B) fatigued.

T07.P24
LEARNING AND CONTROL MODEL OF THE ARM FOR MAINTAINING POSITIONS WITH DIFFERENT WEIGHTS ON HAND

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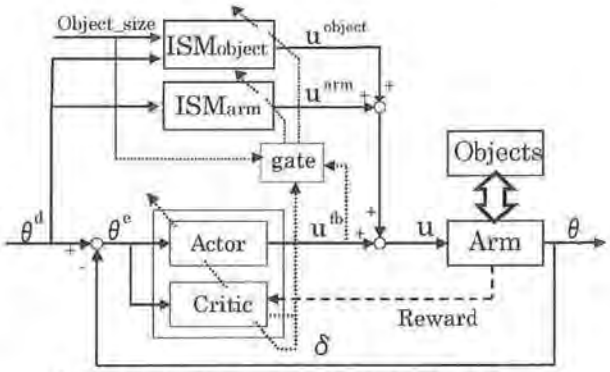
AIMS: Our aim is to find out an arm-control model that can explain how humans control and learn motor command of each muscle for maintaining positions in interaction with objects. Everyday life humans do such movements by generating motor commands appropriate to a task. However, it is not a simple problem to generate appropriate motor commands since there are many combinations even in generating one same joint torque. Here, we propose an arm-control model that acquires motor commands by online learning, needed to maintain arm posture on the sagittal plane while holding one of 4 weights(200g, 400g, 600g, 800g) on hand.

METHODS: Simulation was used to verify the proposed model(see the fiture). Feedback-error learning scheme and actor-critic method were coupled for the implementation of the model and normalized gaussian functions were used as function approximator for Actor-Critic and Inverse Statics Model (ISM). Two-link manipulator with six muslces was used for the arm. Each muscle was modeled as arranging an elastic element and a viscous element in parallel. The learning process during an episode is as follow: 1. a desired position, initial position and object size are chosen randomly and fixed during the episode. The object's wieght is given according to the object size(0, 0.2, 0.4, 0.6, 0.8). 0 indicates no object on hand. 0.2 means 200g object and so on. 2. motor commands are outputted from 'ISMobject', 'ISMarm' and Actor and summed. The summed motor commands are calibrated so that the value comes between zero and one. However, 'u_object' are set to zero if the obejct size is zero. 3. State (θ), which consists of angles and velocities of the shoulder and elbow, is updated according to the dynamics of the arm and objects. And Reward is calculated based on 'u_fb', 'u' and distance error between desired position and real position. 4. Actor-Critic is improved based on TD-error, δ. δ is inputted to the gate which roles as adjusting learning rate of ISM based on δ and deciding which ISM should be learned based on object size. 'ISMarm' is improved when the object size is zero. Otherwise, 'ISMobject' is improved. 5. Repeat from 2 to 4 until the episode ends.

RESULTS: In two ways, we performed tasks of maintaining posture on nine positions while holding an object on hand. One is performed using the proposed model. the other is performed using 'ISMarm' and 'ISMobject' to test if the task is possible in feedforward way. In both cases, the distance errors were less than 3cm on all positions except one position at 400g. And we compared motor commands when keeping posture on a position with different weights. the motor commands increases as the weights of objects get heavier.

CONCLUSIONS: We proposed a learning and control model of the arm on the task of maintaining positions with different wieghts on hand. In the tasks, we verified that the proposed model controls and acquires motor commands correctly on-line. the learned policy considerd humanlike compared to robot's policy which prepared high impedance whether the weights on hand is changed or not.



Caption: Proposed learning and control model of the arm.

T07.P25
IN-PHASE MUSCLE ACTIVATION MAKES IT EASIER TO MOVE IPSILATERAL HAND AND FOOT IN OPPOSITE DIRECTIONS

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AIMS: The aim of the present study was to investigate the influence of the coupling of the muscle activation on the performance of the cyclical coordination of the ipsilateral hand and foot.

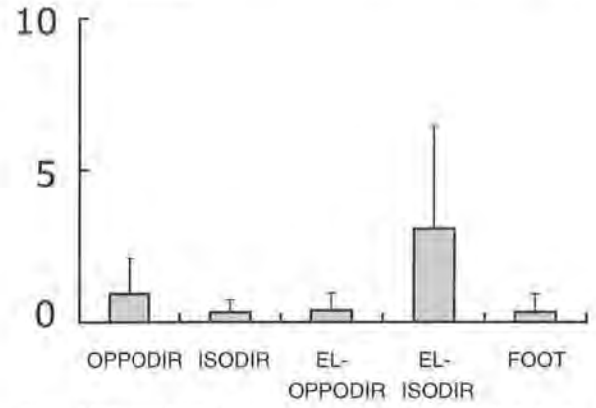
METHODS: The subjects (n=6) rested comfortably in a supine position on a bed. The right forearm was supine and supported in 30 to 40 degrees elblow flexed position. The right lower leg was supported in the horizontal position with a 16 cm height

box. The right hand and foot were placed on plates that were connected to frictionless shafts, which enable the wrist and ankle to move in the saggital plane freely. The angular displacements of the wrist and ankle joints were measured using potentiometerc technique. The subjects performed the cyclical flexion-extension movements of the hand (HAND) or foot (FOOT), the cyclical coordination of the hand and foot in the iso-directions (ISODIR) or opposite-directions (OPPODIR). To change the coupling of wrist joint angle and the activation of wrist muscles, an elastic load against wrist flexion was connected to the plate of the hand. The HAND, ISODIR, and OPPODIR tasks were also performed under this loaded condition (EL-HAND, EL-ISODIR, and EL-OPPODIR, respectively). The subjects performed each task with their eyes closed at a slow (1.5 Hz), moderate (1.75 Hz), and fast (2.0 Hz) frequency prescribed by the auditory metronome (one subject performed tasks at 1.25, 1.5, and 1.75 Hz). Surface electromyograpic activity of the extensor carpi radialis (ECR), flexor carpi ulnaris (FCU), tibialis anterior (TA), gastrocnemius medialis (GAS), and soleus (SOL) was recorded. Each period of the hand cycle was compared to the corresponding period of the foot cycle, then the differnce in time between the mid-point of the two periods was calculated and expressed in degrees of angular displacement, taking the hand period as a reference. When a relative phase was 0±90° in the iso-direction coupling tasks or 180±90° in the opposite-direction coupling tasks, we considered the task was successfully performed. All data were taken from 3rd to17th cycle (15 cycles).

RESULTS: Over 99% success rate of the instructed task was observed in the ISODIR, EL-ISODIR, and EL-OPPODIR. The success rate of the OPPODIR was 97%, 84%, and 78% for slow, moderate, fast frequency, respectively.

An agonist wrist muscle for unloaded and loaded tasks was ECR and FCU, respectively. Therefore, wrist and foot muscles were activated in-phase in the ISODIR and EL-OPPODIR, and anti-phase in the OPPODIR and EL-ISODIR. In the EL-ISODIR, GAS was activated during dorsiflexion phase (i.e., in-phase activation of wrist and foot muscles), though it was almost inactive in the FOOT.

CONCLUSIONS: It is concluded that in-phase muscle activation makes it easier to move ipsilateral hand and foot in opposite directionis.



Mean EMG amplitude (μV) of the gastrocnemius medialis in the dorsiflexion phase. (mean±SD, n=6)

This study was partly supported by the "Establishment of Consolidated Research Institute for Advanced Science and Medical Care" Project, Ministry of Education, Culture, Sports, Science and Technology, Japan.

Mechanomyogram

TWO-DIMENSIONAL SPATIAL DISTRIBUTION OF SURFACE MECHANOMYOGRAPHY RESPONSE TO SINGLE MOTOR UNIT ACTIVITY

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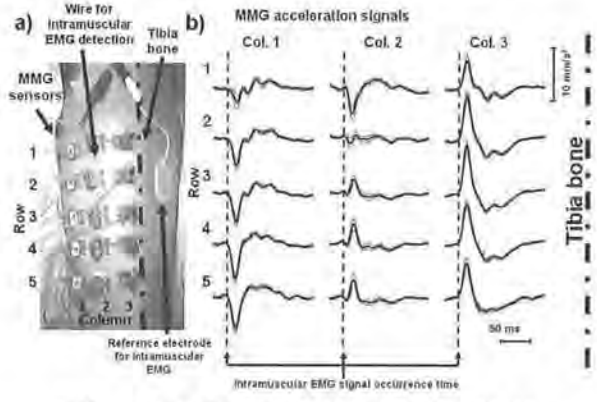
AIMS: The aim of the study was to analyse single motor unit (MU) mechanomyographic (MMG) signals detected on a number of locations on the surface of the tibialis anterior muscle.
METHODS: MMG signals were detected with a two-dimensional array of 15 uniaxial accelerometers arranged on a 3 5 grid with 20-mm inter-accelerometer distance (IAD). The location of the innervation zone corresponded to the accelerometer in the second row and second column (Figure, part a).
The accelerometers were connected to a custom made multichannel MMG amplifier. Intramuscular electromyographic (EMG) signals were detected with two fine wire electrodes (A-M Systems, Carlsborg, WA, USA) and decomposed in order to extract the discharge pattern of the detected motor units. The intramuscular action potentials were used as triggers for averaging the interference MMG signals for the 15 accelerometers in order to extract the contribution of single motor units.
The subjects were asked to perform a low-force contraction in order to keep the discharge frequency of one motor unit (feedback motor unit) at ~8 pulses per second for 2 min with the intramuscular EMG signals as a visual feedback. The task was performed 3 times increasing the contraction level in order to recruit progressively larger motor units. A map of the muscle surface vibration was obtained for each MU.
RESULTS: 23 motor units were identified from the 11 subjects. The surface MMG signals showed a similar spatial distribution of acceleration (Figure, part b). Negative acceleration (towards the inner part of the muscle) was observed at the lateral column of sensors, while acceleration was positive in the medial portion of the muscle, close to the tibia bone. The double integrated signals provided the surface muscle displacement. A negative deflection of the skin surface was observed in the lateral part, as opposite to the medial part. The peak value of the acceleration signal depended on the transversal position (ANOVA: $F = 113$; $P < 0.001$), with negative values laterally and positive values medially. The three columns showed different peak values (SNK: $P < 0.001$).
CONCLUSIONS: A new method for assessing distribution of skin acceleration due to fiber contraction has been developed. The spatial distribution of acceleration is directly related to the displacement and force produced by the motor unit and provides insight into the motor unit physiology and anatomy.



a) Detail of the MMG sensors located on the right leg.
b) averaged (±SE) MMG response of the 23 identified motor units

The Danish Technical Research Council supported this study.

EFFECT OF SKIN TEMPERATURE ON ELECTROMYOGRAM AND MECHANOMYOGRAM DURING BRIEF ISOMETRIC CONTRACTION

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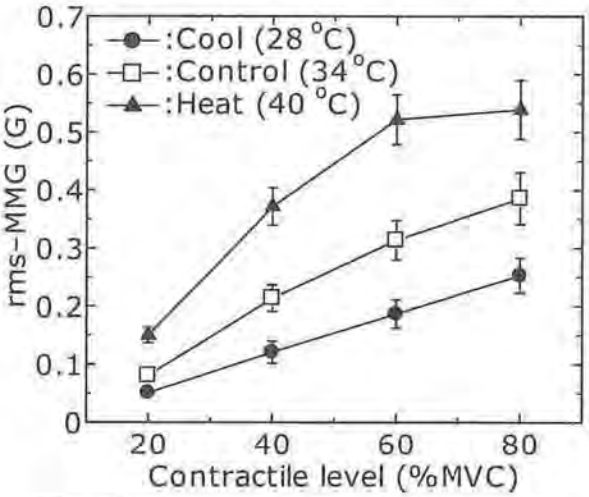
AIMS: Mechanomyogram (MMG) is mechanical counterpart of myoelectric activity and it has gained considerable attention as a new noninvasive tool to investigate the muscular functions. The main mechanism of MMG generation had been considered to be pressure waves produced by lateral expansion of a number of active muscle fibers. It is well known that the changing of muscle temperature concerns the electrical and mechanical function (i.e., electromyogram: EMG and contraction torque, respectively) of the muscle. The aim of this study is mainly examined to elucidate the relation between the skin temperature and MMG signal properties depending on the contractile force.
METHODS: Ten healthy male volunteers, aged 22.8±0.7 (mean±SE) years, participated in this study. The reference condition of skin temperature was attained in room air of 23-25 °C that resulted in the skin temperature of about 34 °C which was called "control" condition. The muscles of upper arm were cooled with over 30 min down to a skin temperature of 28 °C (i.e., "cool" condition). At some other day, the muscles were heated with over 30 min up to a 40 °C (i.e., "heat" condition). In each skin temperature, the EMG and MMG signals were measured on biceps brachii muscle during brief isometric contraction at level of 20%, 40%, 60%, and 80% MVC. The surface EMG signal was picked up by the bipolar Ag/AgCl electrodes (5mm pick-up diameter, 20 mm inter-electrode) and the MMG signal was detected by the piezo-electric accelerometer with weight of 2g (9G111BW, NEC Sanei, Japan). The root mean square amplitude (RMS) was computed from both signals of EMG and MMG (i.e., rms-EMG and rms-MMG, respectively). Two way repeared-measures ANOVA was used to determine differences between multiple groups, using a conservative (Greenhouse-Geisser) *F* test.



Effects of skin temperature on rms-MMG during isometric contraction. Value is denoted by mean±SE for n=10

RESULTS: The significant difference of MVC during elbow flexion was not recognized among the thermal conditions. The rms-EMG and rms-MMG linearly increased depending on the contractile level except for heat condition of MMG ($P<0.01$). In heat condition, the rms-MMG progressively increased in response to increasing up to 60% MVC, however it was nearly unchanged at contractile force higher than 60% MVC. The rms-EMG was not significantly influenced by the skin temperature. The rms-MMG significantly increased depending on the skin temperature at each contractile level ($P<0.01$) as shown in Figure. There were significant

interactions between contractile force and skin temperature for rms-MMG ($P<0.01$). These results might be related to the contraction properties (e.g., contraction time and relaxation time) of muscle fibers and the viscoelastic properties of muscular tissue.
CONCLUSIONS: The results were obtained as the following. (1) rms-EMG was not almost influenced by the skin temperature. (2) rms-MMG significantly increased with the increasing of skin temperature. These data can be extended to the notion that the MMG is a reliable method to investigate muscular function under a wide range of physiological conditions.

MECHANOMYOGRAPHIC TOPOGRAPHICAL MAPS IN ISOMETRIC CONTRACTIONS

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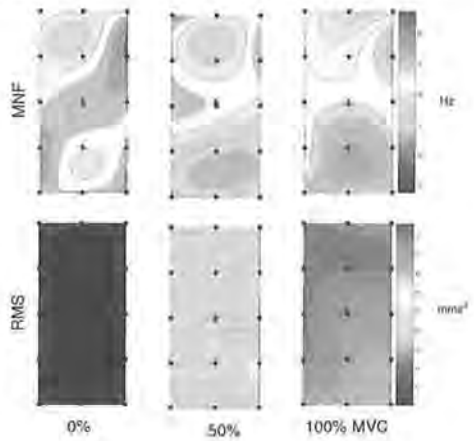
AIMS: The aim of the study was to investigate spatial inhomogeneity in surface mechanomyographic (MMG) muscle activity and its dependency on contraction level.
METHODS: MMG signals were detected over the tibialis anterior muscle of 11 healthy volunteers (age, mean ± SD, 28.2 ± 4.3 yr) with a 5x3 grid of accelerometers. After measuring the maximal voluntary contraction (MVC) force, the subjects performed 11 3-s long isometric contractions at forces in the range 0-100% MVC (10% increment, randomised order). Two-dimensional maps of root mean square and mean power spectral frequency were obtained from the signals. The centre of gravity and entropy (degree of homogeneity) were further computed from the root mean square and mean power spectral frequency maps. Data were analyzed with a mixed model ANOVA.
RESULTS: The surface MMG root mean square increased ($F=11.4$, $P<0.0001$) and entropy decreased ($F=3.8$, $P<0.05$) with force. Root mean square did not depend on location and its center of gravity did not change with force. Mean power frequency was larger in the middle column with respect to the lateral and distal locations ($F=7.0$, $P<0.05$) and its centre of gravity changed with contraction force (for x- and y- position: $F=4.3$, $P<0.001$ and $F=7.7$, $P<0.0001$, respectively; Figure).



Average root mean square (RMS) and mean power frequency (MNF) maps at 0, 50 and 100 % MVC. "■" represent the position of the centre of gravity and "○" represent the position of the accelerometers

CONCLUSIONS: The tibialis anterior was activated uniformly, as assessed by MMG, over the whole contraction range as no spatial changes with force were observed in MMG amplitude (Figure). On the contrary, spatial changes occurred in the frequency estimator's MMG maps, highlighting the complexity of MMG spectral changes with increasing force. Two-dimensional arrays of accelerometers may provide new insights into the generation of MMG signals.

The Danish Technical Research Council supported this study

INFLUENCE OF INSTANTEOUS DISCHARGE RATE ON MOTOR UNIT CONTRIBUTION TO MECHANOMYOGRAM

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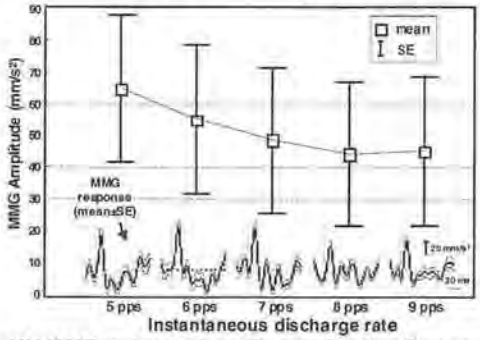
AIMS: The aim of the study was to investigate the effect of instantaneous discharge rate on surface mechanomyogram (MMG) responses to single motor unit (MU) activity. For this purpose, intramuscularly detected single MU action potentials (MUAPs) were used as triggers to average the interference MMG signal and extract the corresponding MU MMG response.
METHODS: MMG and intramuscular EMG signals were detected from the dominant tibialis anterior muscle of 11 male subjects (age, 25.6±5.5 yr). The leg was horizontal with the foot fixed in an isometric force dynamometer at 110° joint ankle. Monopolar intramuscular EMG was detected with a fine wire electrode made of Teflon coated stainless steel (A-M Systems, Carlsborg, WA, USA) inserted by a 23G needle into the muscle belly. An accelerometer (0.5 g mass) for surface MMG detection was placed over the muscle ~1 cm proximal from wire insertion. The subject was asked to modulate the torque during ankle flexion in order to isolate the activity of a single MU (target MU) with audio and visual feedback on the intramuscular EMG. Two trials of 2 min each were performed: 1) activation of the target MU at the minimum discharge rate; 2) activation of the target MU at a higher discharge rate just before recruitment of an additional detectable MU. MUAPs were identified from the intramuscular EMG with a decomposition algorithm previously described [1]. Discharges were divided in 5 groups corresponding to an instantaneous discharge rate (with respect to the previous discharge) of 5-9 pulses per second (pps) (1 pps increment). The discharges in each group were used to trigger the averaging of the interference MMG (over the 80-ms windows; 50 triggers for each group), to extract the responses of the target MU at the 5 discharge rates. One-way repeated measures analysis of variance (ANOVA) with Student-Newman-Keuls (SNK) post-hoc comparison was applied on single MU MMG peak-to-peak amplitude with instantaneous discharge rate as factor.
RESULTS: The Figure shows representative MMG responses and average peak-to-peak amplitude as function of instantaneous discharge rate. Single MU MMG amplitude decreased with increasing discharge rate ($F=2.76$; $P<0.05$), and was different between 5 pps and 9 pps (SNK: $P<0.05$).
CONCLUSION: Small changes (<5 pps) in MU discharge rate have an influence on the contribution of single MU to the interference MMG at low contraction forces. This indicates high non-linearity in summation of MU contributions into the MMG signal and should be considered when inferring MU control strategies from MMG amplitude.



Single MU MMG peak-to-peak amplitude as function of instantaneous discharge rate. Representative averaged MMG responses for each discharge rate are also shown (mean±SE over 50 MUAPs)

[1] Farina D et al., J Neurosci Methods. 2002;115:1-12
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T08.P01
THE ESTIMATION METHOD OF MAXIMUM VOLUNTARILY CONTRACTION FORCE BASED ON MECHANOMYOGRAM

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AIMS: Generally, a load for the resistance training in rehabilitation is decided based on the maximum voluntarily contraction force (MVC) of each muscle. Therefore we should know the MVCs for deciding the load. However, measurement of MVCs is difficult; for example, muscles and tendons may be hurt by the measurement of MVCs, because a muscle generates enormous force. Thus, the estimation method of MVCs is needed.
One of reports about the relation between Mechanomyogram (MMG) and a muscular force indicates that root mean square (RMS) of MMG, which be measured from the biceps brachii muscle (BB), drastically increases at approximately 20% MVC during ramp contraction.
The purpose of this study was to confirm the reproducibility of the point of % MVC that indicates the drastic increase of MMG for development of MVC estimation method by MMG.
METHODS: The healthy subjects (ten males, 22.8±2.6 years old [mean± standard deviation]) participated in this study. They gave their informed consent to the study. They were required to perform isometric contraction of the right elbow flexors. The angle between arm and forearm was 90 degree (by reference to full elbow extension).
At first, theirs MVC of BB were measured. The MVC was defined as the strongest of two trials of maximum voluntarily contractions for lasting 3 seconds. Next, MMG of BB, surface electromyogram (sEMG) of BB, the muscular force of BB and sEMG of triceps brachii muscle (TB) were measured during isometric voluntary contraction at the same time. They maintained the muscular force at 10% MVC for 2 seconds, and then he gradually increased the muscular force to 50% MVC in 8 seconds (5% MVC/s). Each subject repeated the measurement in different speed, that is, the 2nd trial was 8% MVC/s and the 3rd trial was 10% MVC/s.
They practiced the trial for accustoming it before the measurement.

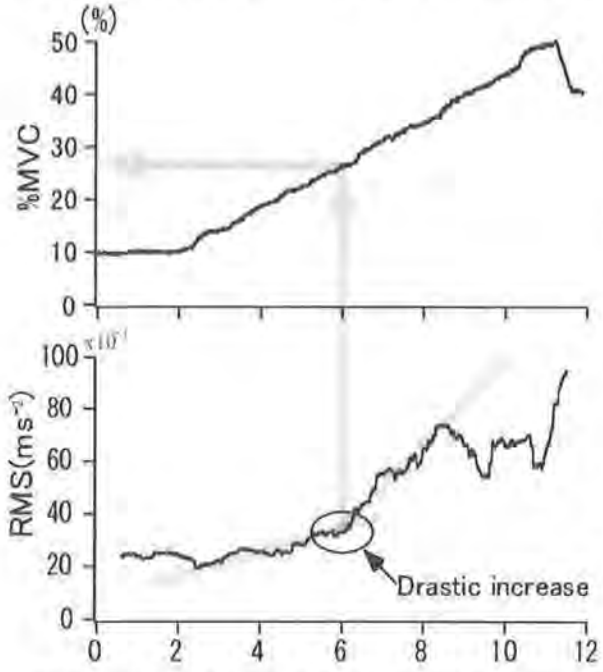

Fig.1. A typical set of %MVC and RMS. Indicated the drastic increase of RMS.

After each trial, they rested for 30 minutes to avoid the fatigue by the trial.
RESULTS: We confirmed that the muscular force increased linearly from 2 second after the start of measurement by muscular force and that the antagonist was not activated by the measurement of TB EMG. All the measurement for each subject indicated a similar tendency. RMSs of MMG were computed in epochs of 1s with 99.9% overlapping. Fig.1 illustrated an example of measurement, the drastic increase of RMS occurred in all subjects and all measurements. The drastic increase of MMG occurred at 25.5±4.7, 25.4±2.5 and 25.8±2.0% MVC on 5% MVC/s, 8% MVC/s and 10% MVC/s, respectively. From the result, it was not indicated that the difference of %/MVC/s affected %MVC. It is estimated that MVC should be approximately one hundred-25ths of the force that show the drastic increase of RMS.
CONCLUSIONS: It is confirmed that the reproducibility of the %MVC which is occurred the drastic increase. It is proposed the estimation method of MVC based on MMG. The method estimated MVC of the biceps brachii muscle of male of 20s from low level contraction.

T08.P02
TIME-FREQUENCY ANALYSIS OF NONSTATIONARY MECHANOMYOGRAM RECORDING DURING SUSTAINED ISOMETRIC CONTRACTION OF BICEPS BRACHII MUSCLES

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AIMS: It has been reported that a mechanomyogram (MMG) reflects a motor unit activation strategy associated with its recruitment and firing rate. The aim of this study is to examine nonstationary behavior of MMG signals during sustained contractions at constant level of force until the beginning of force decrease using a time-frequency analysis method, and to determine whether MMG reflects the specific motor unit activation strategy resulting from muscle fatigue.
METHODS: Ten healthy male adults (age: 23.8±2.7 years) participated in this study. The subjects were performed isometric voluntary contractions of biceps brachii muscles at 20 and 80% of maximal voluntary contraction (20 and 80% MVC) with the elbow joints flexed at 90 degrees. The MMG was detected with a small-sized accelerometer secured over the belly of biceps brachii muscles with adhesive tape. The short-time Fourier transform was used to calculate the root mean squared amplitude (RMS) and mean power frequency (MPF) of the MMG during exhausting isometric contractions. From a time series of the MMG recording, short segments with a period of 0.6 s were cut every 0.1 s using Gaussian function window with the standard deviation of 0.3 s. The power spectral density function (PSD) for each segment was then estimated by the fast Fourier transform algrithm. The RMS and MPF in each data segment were computed from the PSD.
RESULTS & DISCUSSION: In the 20% MVC trial, the RMS began to decrease temporarily to 0.86±0.12, and then increased progressively to 2.99±1.58. The MPF increased initially to 1.11±0.06, and then remained almost constant. In the 80% MVC trial, the RMS continued to decrease to 0.70±0.13. The decrement was marked at the onset of contraction, and then became slow. An initially increase in the MPF was followed by a gradual decrease to 0.85±0.14. These trends in the RMS and MPF seem to reflect an alteration in the motor unit activation strategy resulting from muscle fatigue. The MMG is considered to be one of the useful tools in monitoring muscle fatigue.

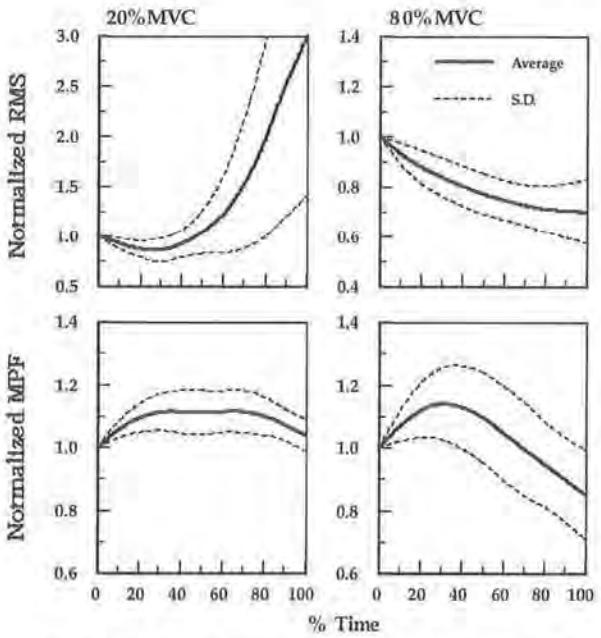

Figure: Interindividual means and standard deviations of the normalized spline curves of the RMS and MPF as a function of percentage of the sustaining limit time (% Time).

T08.P03
MEASUREMENT OF ACCELERATION / DISPLACEMENT MMG IN TETANIC CONTRACTION

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AIMS: It is expected that the contraction function of the muscle could be estimated by Mechanomyogram (MMG) from the different viewpoint from EMG, because the MMG reflects the small vibration originated from the skeletal muscle contraction. The MMG is generally measured using the accelerometer and it is known that the amplitude of acceleration MMG (MMGg) decreases during tetanic contraction. In this study, the displacement MMG (MMGd) in the tetanic contraction was measured using a laser displacement sensor, and the relationship among the contraction force, the MMGg and MMGd was discussed.

METHODS: The rats of 12-18 week-old and of weight 300-500g were used. The tibial nerve of rat under the anesthesia was electro-stimulated using Ag-AgCl electrodes, and the isometric contraciton of gastrocnemius muscle was induced as the foot was fixed. The electro-stimulation was repeatedly done using negative pulse of 1ms duration at 2-100Hz and had stimulation period in 1s and idle period in 1s. The piezoelectric accelerometer (PV-08A, RION) of 0.7g weight and 1-25kHz was used in the MMGg measurement, and the CCD laser displacement sensor (LK-G 155, KEYENCE) whose measuring spot is 120 μm in diameter and resolution is 0.5 μm, was used in the measurement of MMGd. The accelerometer was placed on the removed skin. The load senor was placed on the sole of foot in order to measure the contraction force, and the angle of ankle joint was fixed in 90 degrees.

RESULTS: When the gastrocnemius muscle was dyed and the ratio of muscle fiber types was counted, the type I was 4% and the type II was 96%. When the stimulation frequency increased and exceeded the threshold of frequency, the tetanic contraction was caused by the continuous contraction that the muscle was compulsorily contracted by the coming stimulation before the contracted muscle once was perfectly released. The tetanic contraction was caused by the fusion of muscle contraction, and made the base line (MF-DC) of muscle force (MF) rise, shown in Figure. the fluctuation of MF (MF-AC) gradually decreased, as the fluctuation of muscle contraction decreased. The MMGg decreased when the tetanus was promoted, as well as the former report (1). On the other hands, the baseline of MMGd (MMGd-DC) increased like the muscle force, and its fluctuation (MMGd-AC) decreased like the MMGg-AC. It was possible to estimate the amplitude of muscular contraction from MMGg within the small muscle force until now, but it was difficult to estimate it in the large contraction exceeding 80% MVC, since the MMGg decreased. Then it was indicated that the ampliitude of contraction could be estimated over the whole contraction of the muscle including the tetanus, when the MMGd was measured.

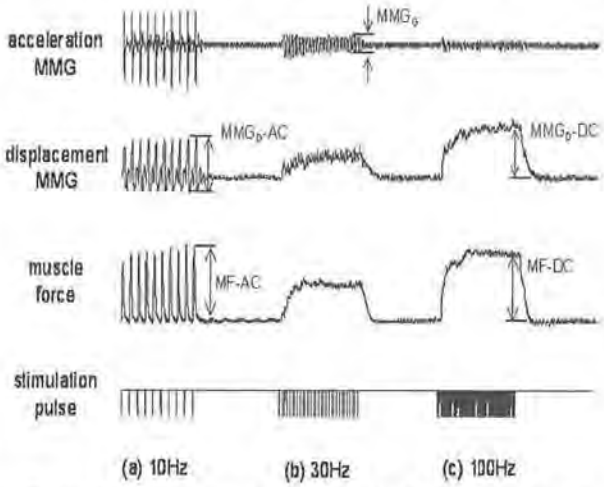

Figure: Acceleration and displacement MMG, muscle force and stimulation pulse at 10, 30 and 100 Hz.

CONCLUSION: It was difficult to estimate the amplitude of muscle contraction over the whole contraction, since the MMGg decreased in the large contraction. In the MMGd, it was possible to obtain not only the MMG signal proportional to the amplitude of contraction but also the signal proportional to the MMGg. Then the effectiveness of MMGd was confirmed.

1) Orizio, C., Critical Reviews in Biomedical Engineering, pp.201-243, 1993.

T08.P04
TETANIC CONTRACTION PROPERTIES OF DIFFERENT MUSCLE FIBERS

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AIMS: Electromyogram (EMG) which can measure the electrical activity of the muscle, is generally used for the evaluation of the muscle function. Mechanomyogram (MMG) which can measure the slight vibration of muscle contraction, can evaluate the mechanical function of the muscle. As one of the features of MMG, decreasing of its amplitude appears in the tetanic contraction. This phenomenon arises by the increase of firing rate of the motor units. The purpose of this study is to clarify the contraction properties of different muscle fiber. The MMG and muscle force of the gastrocnemius and the soleus muscle of rats were measured as the frequency of the electrical stimulation increased.

METHODS: The rats whose body weights were 300-500g, and ages were 12-18 weeks were used for the experiment. The gastrocnemius and the soleus muscle were tested under the anesthesia. The nerves, which did not control the gastrocnemius and the soleus, were cut off. The electrical stimulation, which was a negative pulse and whose duration was 1ms, was used, and the stimulation frequency increases from 5 to 50 Hz during 5 seconds.

Laser displacement sensor (LK-G155, KEYENCE) was used for the MMG measurement. The MMG was measured on the removed skin. The muscle force was measured by a load cell at the planta pedis. The MMG signals and muscle force were recorded at sampling rate of 1 kHz with a low-pass filter of 300 Hz.

RESULTS: The baseline of MMG increased and the variation component of the MMG decreased in the tetanic contraction. Figure showed the base line fluctuation of MMG when the stimulation frequency increased from 5 to 50 Hz. It showed that the tetanic contraction promoted at 14-47.5 Hz in the gastrocnemius, and at 8-25 Hz in the soleus. The stimulation frequency in the soleus, at which the tetanic contraction arised, was lower than that in the gastrocnemius. When the electrical stimulation was quickly repeated, the muscle force seemed to be increased by the integration of the twitch contraction. The period until the twitch force reached the maximum from the start of the stimulation was defined as CT (contraction time), and the period until the twitch force disappeared from the maximum was defined as RT (relaxation time). If the coming stimulation is made between CT and CT+RT, the tetanic contraction is induced. In case of the gastrocnemius, CT and CT+RT were 20ms and 66ms, respectively. It seemed that the tetanic contraction started at about 15.2 Hz (=1/(CT+RT) = 1/66ms) and reached the complete tetanus at about 50Hz (=1/CT=1/20ms). In case of the soleus, the tetanic contraction was promoted at 9.1-25 Hz. These estimated frequencies were the same results as the Figure.

CONCLUSIONS: The frequency of electrical stimulation at which the soleus induces the tetanic contraction was lower than that of the gastrocnemius. These stimulation frequencies could be estimated by the measurement of CT and RT.

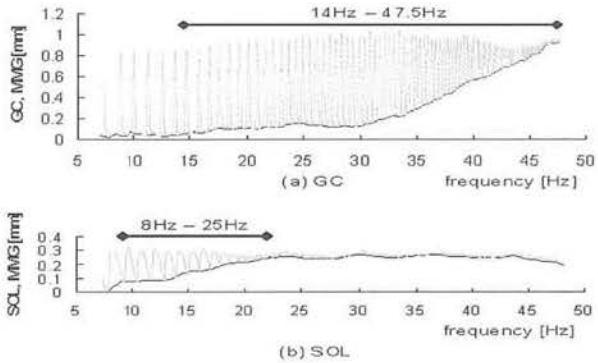

Figure: The baseline fluctuation of the MMG as the stimulation frequency increased from 5Hz to 50 Hz.

T08.P05
MODULATION OF EMG AND MMG SIGNALS DURING A RAMP CONTRACTION OF THE KNEE EXTENSORS

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AIMS: It has been proposed [1,2] that, for the Biceps Brachii (BB) and the First Dorsal Interosseous (FDI) the root mean square (RMS) of the mechanomyographic (MMG) signal reflects the recruitment of motor units while producing a ramp contraction and that the mean power frequency (MPF) of this MMG signal reflects their firing rate. The aims of the present study were to attempt to replicate these findings on the quadriceps and to investigate differences between muscular components and genders.

METHODS: The EMG and MMG signals of the Vastus Medialis (VM), Vastus Lateralis (VL) and Rectus Femoris (RF) muscles of 22 healthy subjects (10 women and 12 men) were recorded during an isometric ramp contraction in extension of the knee. This contraction lasted 5s and ranged from 0 to 100% of the maximal voluntary contraction (MVC). This was done using the Biodex Dynamometer with the knee positioned at 50° of flexion. Special EMG/MMG surface electrodes were used [3]. The slope values of the median frequency of the power spectrum (Fmd)/Moment and of the RMS/Moment relationships of the EMG and MMG signals were obtained for each muscle investigated.

RESULTS: Overall, no significant differences were obtained (two-way ANOVA) between muscles components or genders in the slopes of the relationships investigated. Only one difference between the muscles ($p=0.014$) in the MMG-Fmd/Moment was found. On a more qualitative type analysis, it was observed that the MMG-RMS/Moment graphs leveled off around 70% MVC suggesting that the recruitment of motor units was over or reduced at this level. However, a concomitant increase of the MMG-Fmd/Moment values at this level was not observed on the plots. This would have indicated the presence of an increased firing rate in order to compensate for the leveling off of motor unit recruitment.

DISCUSSION and CONCLUSIONS: Our results are not as conclusive as those of Akataki et al. [1, 2] that suggested that the non-invasive MMG-MPF/Force and MMG-RMS/Force relationships are sensitive to the firing rate and recruitment of motor units as well as to their interplay in the production of a muscular contraction. Their observations were made from the BB and FDI muscles. The muscular components used in the present study were possibly not ideal in terms of depicting the use of firing rate to increase force production once recruitment of motor units is completed.

[1] Akataki, K., et al. (2001) Eur J Appl Physiol 84: 19-25.
[2] Akataki, K., et al. (2003) Eur J Appl Physiol 89: 520-525.
[3] Cescon, C., et al. (2002). XIV ISEK Congress, Vienna, Austria.

T08.P06
COHERENCE ANALYSIS BETWEEN MECHANOMYOGRAM AND ELECTROMYOGRAM OF THE BICEPS BRACHII DURING MAXIMAL ISOMETRIC VOLUNTARY CONTRACTION

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AIMS: Simultaneous measurement of mechanomyography (MMG) and electromyography (EMG) are useful for describing motor control strategies (Beck et al., 2004). As power spectra of both signals contain the motor unit firing rate information (Orizio et al., 2003; De Luca, 1997), the cross-spectrum (Orizio 1992, 1993) and coherence (Orizio 1991) analysis between EMG and MMG signals can be used as noninvasive tool to identify the dominant motor units firing rate and the degree of its modulation. A new approach that considers across subjects and trials variability was applied to estimate the EMG/MMG coherence for a single subject and for the entire group of subjects.

The aim of the study was to examine the motor control strategy of the biceps brachii muscle (BB) during maximal isometric voluntary contraction (MVC) using the new analysis of coherence between EMG and MMG signals.

METHODS: Twenty two young females (age 20±1 yr) participated in the study. The EMG and MMG signals from the BB muscle were measured at an optimal angle during right elbow flexion using the custom-made EMG/MMG probe. The testing session consisted of five trials of 2 or 3-sec MVC with simultaneous recording of force, EMG and MMG signals and only three best trials, without artifacts, were chosen for statistical analysis. From each of three trials 1s interval covering most stationary EMG and MMG signals were chosen to assess coherence (C). The C

was calculated with 2Hz resolution using scripts in Matlab environment. The script implements a classical method to estimate coefficient of coherence (Rosenberg et al., 1989). Then, the matrix of coefficients was divided into non-overlapping 8Hz segments. A median value of C coefficient was calculated for three trials and four frequencies for each subject and its statistical significance was examined for the entire group of subjects. Since the median value is less sensitive to extreme scores than the mean, the median should be a better measure for skewed distributions of C coefficient between EMG and MMG signals.

RESULTS: The coherence between EMG and MMG signals of the BB during MVC was statistically significant in the frequency range of 10-16 Hz and 34-56 Hz in the median method while in the frequency range of 10-16 Hz and 34-64 Hz in the mean method.

frequency ranges [Hz]		2÷8	10÷16	18÷24	26÷32	34÷40	42÷48	50÷56	58÷64
coherence coefficient	median method	0.454	0.572*	0.441	0.489	0.527*	0.538*	0.542*	0.486
	± SD	0.115	0.120	0.109	0.142	0.133	0.148	0.142	0.158
	mean method	0.479	0.554*	0.467	0.469	0.530*	0.536*	0.527*	0.500*
	± SD	0.081	0.079	0.084	0.092	0.074	0.083	0.111	0.103

CONCLUSIONS: The median method of EMG/MMG coherence estimation during MVC seems to be more selective and sensitive than the mean at the 58-64Hz frequency range, and it can provide a description of a dominant motor units firing rate.

T08.P07
THE ESTIMATION OF MECHANICAL PROPERTY BY THE FREQUENCY ANALYSIS OF THE MECHANOMYOGRAM

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AIMS: Because Mechanomyogram (MMG) is generated by the contraction of muscle fiber, MMG reflects the mechanical activity of muscle. The analysis of MMG is effective for the estimation of the change of mechanical property. The purpose of this study is to clarify a change of mechanical property by the frequency analysis of MMG. For the frequency analysis, we use Matching pursuit method, which can analyze the property of an original signal very precisely.

METHODS: The matching pursuit method (MP) decomposes the target signal into a sum of waveforms that belong to a redundant dictionary of functions. These waveforms are selected in order to best match signal structures. The target muscle is the biceps brachii muscle. When the subjects increased their isometric elbow flexion force from 0 to 90% MVC in 12 seconds, we measured the MMG and force with 1000Hz sampling frequency.

RESULTS: Figure 1 shows the result of frequency analysis of measured MMG. In the range that muscle force is lower than 30% MVC, the frequency component is almost less than 20 Hz. However, in the range higher than 30% MVC, the frequency component of 40 Hz appeared. Above 80% MVC, the frequency component around 60 Hz, whose power is small, is found.

CONCLUSIONS: As the muscle force increases, the high power frequency component shifted to the lower frequency. This results show the change of mechanical property of muscle.

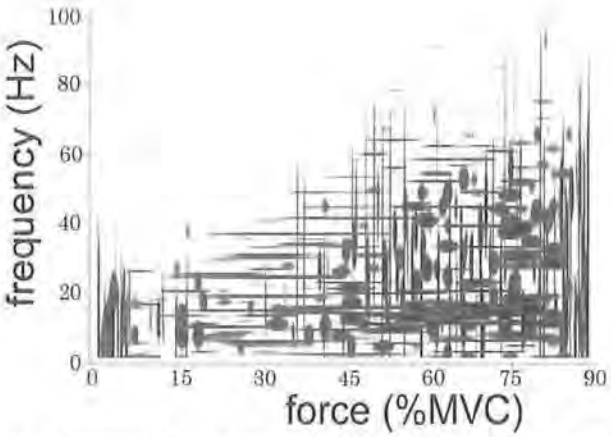

Fig.1 A example of the frequency analysis of MMG by the matching pursuit method

T08.P08
A BIOMECHANICAL INVESTIGATION ON VIBRATION TRANSDUCERS IN MECHANOMYOGRAPHY

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AIMS: Different types of vibration transducers such as accelerometer, condenser microphone, and piezoelectric contact sensor have been used for recording the mechanomyogram (MMG). However, physical characteristics of the MMG transducers and appropriate measurement methods are still undetermined. The aim of the present investigation was specifically to clarify the influence of transducer weight on the MMG recordings and the frequency responses of condenser microphone. Moreover, a vibration mechanism was developed to simulate the MMG behavior on flexible body surface.

CHARACTERISTICS OF MMG TRANSDUCERS: Two identical accelerometers (ACCs) with their own weight of 2 g were secured on the quadriceps muscles to examine the influence of transducer weight. The MMG was measured with different additional weight (2, 4, 10 or 50 g) during isometric voluntary contractions. The additional weight led to an attenuation distortion in the MMG frequency components above approximately 50 Hz. The substantial attenuation began already from additional weight of only 4 g.

A mechanical cylinder-piston system was used to determine the frequency response of condenser microphone (MIC). The MIC air chamber was compressed and released periodically by the piston. The pressure change was recorded with the MIC. The MMG was obtained simultaneously with MIC and ACC from quadriceps muscles during isometric contractions. The MIC output increased linearly with increasing sinusoidal displacement amplitude up to 20 μmp-p with the sensitivity of 79 mV/μm. The MIC responded to the sinusoidal frequency like a high pass-filter with the cut-off frequency of 10 Hz. The displacement of the skin surface was computed as the double integral of the ACC output. The amplitude spectral density function (ASD) of the estimated displacement and the MIC signal was calculated. The ratio of the two ASDs at each frequency was calculated as the actual sensitivity. The frequency response of the actual sensitivity was consistent with that from the mechanical vibration test. Although the actual sensitivity within the frequency range from 10 to 50 Hz was almost constant indicating their linear relationship, its value differed from that from the mechanical test and evaluated approximately one mV/μm. The difference was probably caused

by specific deformation of the skin surface.
VIBRATION SIMULATOR: A vibration mechanism to simulate the MMG behavior consisted of a piezoelectric-actuator as a vibration source, a moving plate, and a rigid frame. The performance of the simulator was determined with the laser displacement meter. It was confirmed that the simulator generated mechanical vibration with any amplitude up to 40 μmp-p and any frequencies up to 70 Hz.
CONCLUSIONS: These results suggest that heavier transducer distorts higher frequency components of the MMG signal and the specific deformation of skin surface affects the performance of the MIC. The developed MMG simulator is considered to have sufficient performance to investigate the MMG transducers detecting the surface displacement since the dominant MMG bandwidth from the displacement type of transducer is up to 50 Hz.

T08.P09
MECHANOMYOGRAPHIC DETERMINATION OF POST-ACTIVATION POTENTIATION IN MYOPATHIES

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AIMS: The potentiation of twitch contraction force after a brief maximum voluntary contraction (MVC) is referred to as the post-activation potentiation (PAP). The potentiation is caused by a pronounced change of contractile property in type-ii fibers. The mechanomyogram (MMG) seems to reflect more directly the contractile property of the muscle than the force recording since it is detected on the surface over the muscle. The PAP determined by the MMG may thus provide non-invasive information to estimate muscle fiber composition. In addition it is considered to be useful as a clinical tool for diagnosis on myopathies with type-II fiber dysfunction. The aim of the present study was to clarify availability of the PAP determination by MMG and to investigate whether the MMG-PAP reflects abnormality of type-II fibers in myopathies.
METHODS: In health male subjects, the twitch contraction in the gastrocnemius (GAS) and soleus (SOL) muscles was by electrical stimulation to the muscle surface respectively before and after a brief MVC in plantar flexion during 10-seconds. The PAP in both the GAS and SOL was determined by the plantar flexion force (FOR-PAP) and the MMG detected from each muscle belly (MMG-PAP) before and after the MVC. In order to elucidate whether the MMG-PAP can be used as a diagnostic index for the myopathies, the biceps brachii (BB) was induced electrically before and after the 10s-MVC in elbow flexion. The MMG was recorded from the muscle belly.
RESULTS: The GAS with higher proportion of type-II fibers showed greater change in both FOR-PAP and MMG-PAP compared with the SOL. Especially the MMG-PAP in GAS was markedly different from that in SOL. The MMG-PAP in patients with myopathies (66±53%) was significantly different from that in normal controls (102±43%). When myopathic patients were divided into dystrophic and non-dystrophic group, the MMG-PAP in the non-dystrophic group (38±20%) was much lower than that in normal controls. The mean fiber determination by the muscle biopsy indicated that type-II fuber atrophy and skewed distribution of fiber size, that corresponded to the lower MMG-PAP.
CONCLUSIONS: The present study demonstrated that the MMG is more sensitive in the PAP determination compared with the force. In addition, the MMG-PAP was closely related to muscle biopsy examination in patients with myopathies. These results suggest that the PAP detemination by the MMG is a useful tool for quantification of muscle contractile property, diagnosis of the type-II fiber atrophy and discrimination of various types of myopathies.

Motor Units

MULTIPLE MOTOR UNIT DISCHARGES IN AN INTRINSIC MUSCLE OF TRANSPLANTED HAND

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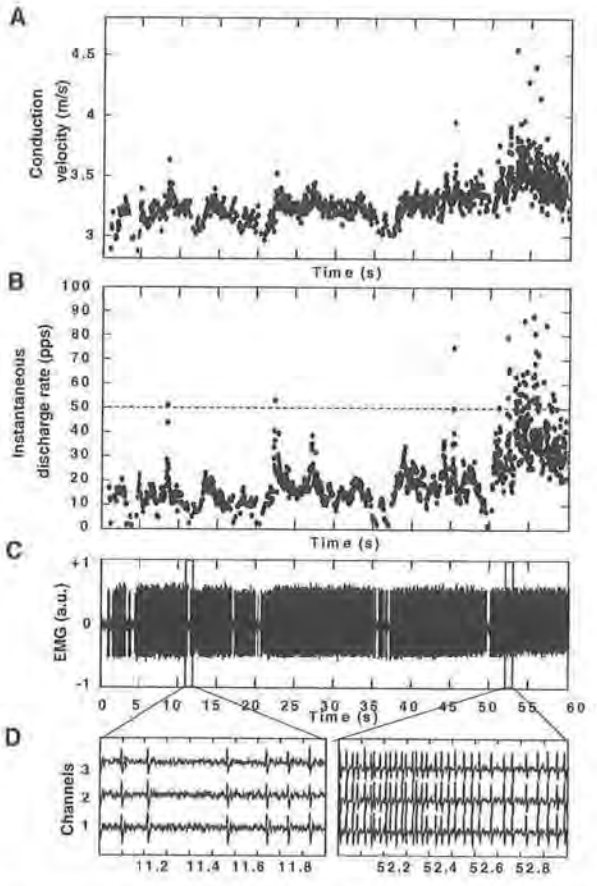
AIMS: The aim of the study was to investigate the control and membrane properties of motor units reinnervated after hand transplantation.
METHODS: The subject investigated was a 35-year-old male who had lost his right dominant hand when he was 13. The surgical procedure was similar to that followed during hand replantation [1]. Multi-channel surface EMG signals were recorded (16 electrodes, 1-mm diameter, 2.5 mm distance) from the abductor digiti minimi muscle of the transplanted hand. The first set of measures was taken 7 months postoperatively followed by a second evaluation at 11 months and then monthly up to 10 sessions. After first signs of reinnervation (11 months), in each session the subject was asked to increase the activation level from a minimum to a maximum in 60 s (ramp contractions) and, after rest, to maintain a maximal effort for 60 s (sustained contractions). The recorded signals were decomposed into single motor unit action potentials. Discharges closer than 20 ms were considered multiple discharges.



Conduction velocity (A), instantaneous discharge rate (B), raw EMG signal (C), and zoom of two short epochs of the raw EMG (D). Note the close correlation between conduction velocity estimated at the single action potential level and instantaneous discharge rate

RESULTS: Results are reported for a motor unit which could be identified in all sessions following reinnervation. In ramp contractions, discharge rate increased from 12.5±4.9 pps (first 5 s) to 27.3±5.3 pps (last 5 s) ($P<0.0001$). Conduction velocity increased ($P<0.0001$) from 4.14±1.34 m/s to 4.60±0.98 m/s and was positively correlated to instantaneous discharge rate in all contractions ($P<0.05$; $R=0.44\pm0.15$; Figure). In sustained contractions, several multiple discharges were identified: 151 doublets, 24 triplets, 2 quadruplets, and 2 quintuplets. The instantaneous discharge rate before a doublet was 33.0±10.2 pps, significantly smaller than that of the double discharge (76.2±40.6 pps) ($P<0.0001$). In doublets, conduction velocity of the second discharge (4.8±1.2 m/s) was higher than that of the preceding discharge (4.5±1.1 m/s; $P<0.01$). For triplets, the discharge rates of second and third discharge were not significantly different (65.9±4.8 pps and 78.7±4.6 pps), but higher than in the pre-discharges (31.3±4.3 pps; $P<0.0001$). Conduction velocity of the second discharge (4.8±1.3 m/s) was higher than that of the pre-discharges (4.3±0.9 m/s; $P<0.05$) while that of the third discharge was not different from the initial value (4.6±1.2 m/s).
CONCLUSIONS: Frequent multiple discharges could be identified in the control of an intrinsic muscle of the transplanted hand. Moreover, the velocity of propagation of the action potentials depended on the instantaneous discharge rate.

[1] Dubernard JM, Owen E, Herzberg G, Lanzetta M, Martin X, Kapila H, Dawahra M, Hakim NS. Human hand allograft: report on first 6 months. Lancet 1999;353(9161):1315-20.

DOUBLET DISCHARGES ARE DEPENDENT ON MOTOR UNIT FIRING RATES IN MOTONEURONS OF YOUNG AND OLDER HUMANS

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Doublet discharges, in which a motor unit fires two action potentials close together in time (typically with an inter-spike interval ≤10 ms), have been demonstrated in both animals and humans. It is thought that these doublets act to augment force production; however, the mechanisms that produce doublets are not fully understood.
AIMS: The purpose of this study was to investigate the occurrence of doublets in young and older humans, during different rates of force production, and to use potential age differences to provide mechanistic insights.
METHODS: Participants included eight young (21.9±3.56 years) and eight older (74.1±8.79 years) individuals, with equal numbers of males and females in each group. Motor unit activity was recorded from the tibialis anterior during isometric dorsiflexion using a four-wire needle electrode. Subjects performed three ramp contractions from zero to 50% maximal voluntary contraction (MVC) force at each of three rates: 10%, 30% and 50% MVC/s.
RESULTS: Overall, the occurrence of doublets was significantly higher in the young than in the older individuals ($p<.001$). However, neither group showed differences in the occurrence of doublets across the three rates of force production ($p>.05$). The force at which doublets occurred ranged from 3.4% to 50% MVC in the young subjects and from 0% to 50% MVC in the older subjects, and was not significantly different between groups ($p=.22$). A weak relationship was found between the recruitment force of the motor units and the force at which the doublets occurred in young ($r^2=.16$, $p<.001$) and older ($r^2=.18$, $p<.001$) subjects, suggesting that doublets did not always occur at the initiation of motor unit firing. The maximal firing rate achieved during the submaximal contraction of those motor units that discharged doublets was significantly higher than those that did not in both age groups ($p<.001$). There was a significant relationship between the firing rate immediately before the doublet and the maximal firing rate of the motor units in young ($r^2=.12$, $p<.003$) and older ($r^2=.66$, $p<.001$) subjects, suggesting that firing rate plays a role in the likelihood that a motor unit discharges doublets. However, maximal firing rates cannot explain the

difference in the occurrence of doublet discharges between young and older subjects, as maximal firing rates (during the submaximal contractions) were not significantly different between the groups (p=.11). The motor unit firing rate of older individuals, however, was closer to maximal firing rate when the doublets were discharged, suggesting that the older individuals required greater descending drive for doublets to occur. The age differences may also be related to the changes in the intrinsic properties of motor units that occur with aging.
CONCLUSIONS: It is therefore suggested that an interaction between descending drive and intrinsic motoneuron properties influences the likelihood that motor units will discharge doublets.

DECOMPOSITION OF SURFACE EMG SIGNALS

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AIMS: To develop a technique for decomposing surface Electromyographic (sEMG) signals into the constituent motor unit action potentials.
METHODS: The sEMG signal is detected with a four-pin surface sensor array. Four channels of differentially amplified sEMG signals are collected. The decomposition is achieved by a set of algorithms that uses our own specially developed knowledge-based Artificial Intelligence framework, previously devised for decomposing indwelling EMG signals. The algorithms have been modified to accomodate the additional complexities that are characteristic of the sEMG signal. They have the capacity to identify the recruitment and derecruitment of motor units, and resolve complex superpositions of several motor unit action potentials. An Iteractive Editor was constructed to further assist in the decomposition when the algorithms were not able to correctly identify the firings. The accuracy was verified by comparing the firings of action potentials from the EMG signals detected externally by the surface sensor array and internally by a needle sensor.
RESULTS: For brief periods of time, in the order of 4 to 5 s, we have identified the firings of up to 9 motor units. But more importantly, we have decomposed up to 6 motor unit action potential trains throughout the full duration of 30 s contractions. In the automatic mode the signals are decomposed with an accuracy ranging from 60 to 80%. With the assistance of the Interactive Editor, the accuracy was greater than 97% over the 30 s duration of the contraction. We have decomposed sucessfully sEMG signals form the Orbicularis Oculi, Platysma, the Tounge, and Tibialis Anterior muscles. It is noteworthy that the sEMG decomposition was able to accurately decompose the signal throughout the unstable muscle contraction such as from the Orbicularis oculi whole the eyelid was "squinting".
With this technique it is possible to investigate the behavior of motor units in muscles that are not easily studied via invasive needle sensors. We found that the inverse relationship between the recruitment threshold and the firing rate previously reported for muscles innervated by spinal nerves is also present in muscles that are innervated by cranial nerves. But, the facial and neck muscles have greater and more widespread values of firing rates than limb muscles - similar to hand muscles.
CONCLUSION: Accurate, useful decomposition of sEMG signals is possible. The "onion skin " reationship exists in facial and neck muscles. The firing rate behavior of these muscles is comparable to that of the intrinsic muscles of the hand.

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MULTI-CHANNEL THIN-FILM ELECTRODE SYSTEMS FOR INTRAMUSCULAR EMG RECORDINGS

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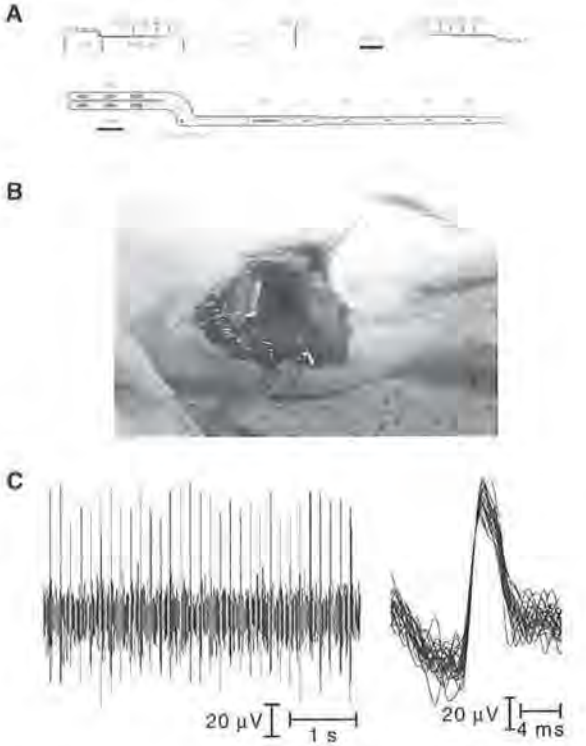
AIMS: Our understanding of motor unit behavior is limited by the near-absence of data on the range of properties within populations of motor units. This is due to the small number of motor units which can be simultaneously observed and investigated with current recording techniques. The aim of the study was to transfer the thin-film electrode array technology, recently proposed for recordings within peripheral nerve fascicles [1], to recordings from muscle fibers. The thin-film technology allows a high number of closely-spaced recording surfaces, thus being promising for sampling from large muscle regions and collect motor unit population data.
METHODS: The system used in this study is a prototype of thin-film system, originally designed for recordings from nerve fibers [1]. It is a microfabricated poly-imide structure, 120-µm wide, 20-µm thick, 1.5-cm long, with 8 circular 40 µm Pt/PtCl recording sites (in the current prototype) distributed along the front and back surfaces (500-µm inter-site spacing). The system was applied for muscle fiber recordings in an anaesthetized adult Wistar rat (M, 5 mo, 350 g) model, in accordance to a protocol approved by the Danish Committee for the Ethical Use of Animals in Research. Surgical access through the biceps femoris lateralis was made to expose the sciatic nerve and the lateral head of the gastrocnemius muscle (Figure). An 80 µm tungsten needle with polyaramid fibers linking the thin-film structure with the needle was used to introduce the structure into the belly of the muscle (Figure), perpendicular to the muscle fibre pinnation. Asynchronous mass activity in the muscle was induced by successive crushing of the sciatic nerve. The EMG signals were amplified (x5000) and high pass filtered (0.1 Hz). Records were made monopolar relative to a nearby reference electrode.



Thin film penetrating electrode design showing layout of the electrode, pad and site positions (A). Experimental set-up for the recordings (B). Example of recorded signals and extraction of single motor unit action potentials (C)

RESULTS: The Figure shows a test recording following nerve crushing in which a single motor unit was identified. The RMS noise level in the test recordings was (mean±SD) 8±3 μV. Motor units could be identified in all test contractions and extracted from the interference EMG with an automatic approach. The mean discharge rate of the identified motor units was 9.3±3.4 pulses per second.
CONCLUSIONS: In this study we propose the use of a new system for the detection of intramuscular EMG signals, based on thin-film technology. The main advantage of the system is the availability of many detection surfaces whose relative location and distance can be accurately designed. This will allow the development of high-density, multi-channel intramuscular EMG recording systems.

[1] Yoshida, K., Hennings, K., Kammer, S., "Acute performance of the thin-film longitudinal intra-fascicular electrode", BioRob 2006, Pisa, Italy, 2006.

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EMGLAB: AN OPEN-SOURCE EMG DECOMPOSITION PROGRAM

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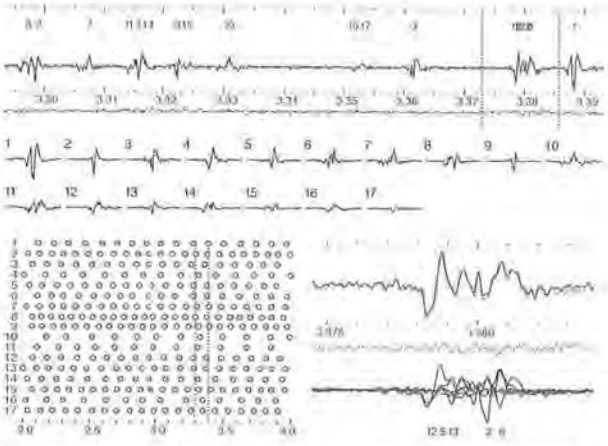
AIMS: Intramuscularly recorded EMG signals provide a potentially rich source of information about motor unit (MU) behavior and architecture. The process of sorting out the discharges of individual MUs is known as EMG decomposition. EMG decomposition methods have been developed in several labs, but they have not successfully transitioned to the wider community. The aim of this project is to promote the advancement and wider use of EMG decomposition by making available decomposition software that we have developed and used over the past twenty years.
METHODS: EMGLAB (McGill et al., *J Neurosci Meth*, 149: 121-133, 2005) is a Matlab program for viewing EMG signals, decomposing them into motor-unit action potential (MUAP) trains, and averaging MUAP waveforms. It provides a convenient graphical interface for displaying and editing results, and advanced algorithms for template matching, resolving superimpositions, and decomposition-triggered averaging.



The screen is divided into four panels that show a segment of the EMG signal and the residual signal af-ter template matching, the templates of the identified MU spikes, the identified discharge patterns, and a close-up of the signal for resolving superimpositions. Graphical point-and-drag commands are available for forming templates, identi-fying spikes, editing identifications, and resolving superimpositions. Here, the small residual and the regularity of the discharge patterns indicate a full and accurate decomposition.
RESULTS: We have used EMGLAB successfully to decompose thousands of EMG signals recorded using conventional needle and fine-wire electrodes from a variety of human muscles. The manual editing capability makes it possible to identify all the activity in many moderately complex signals down to the level of the baseline noise, typically yielding full discharge patterns of ten to twenty simultaneously active MUs. The decomposition-triggered-averaging capability makes it possible to obtain high-signal-to-noise-ratio MUAP waveforms essential for studying MU architecture. There is also a capability to subtract out interfering activity in order to identify and analyze potentials that are difficult to isolate on-line, such as satellite potentials and variable MUAP components. The program supports both single- and multi-channel signals.
CONCLUSIONS: EMGLAB is being made available in an open-source format as a part of an NIH-sponsored internet-based research resource for EMG decomposition. We hope that free dissemination of the program will promote its use as a research tool in various applications in muscle physiology, motor control, kinesiology, and clinical neurophysiology; and that it will encourage wider exchange and discussion of EMG data, greater attention to accuracy and precision, and further innovation.

COHERENCE BETWEEN MOTOR UNIT DISCHARGE IN RESPONSE TO SHARED NEURAL INPUTS

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AIMS: Coherence analysis has revealed the existence of frequency dependent coupling between individual motor units and between EEG and EMG signals. Despite its widespread application, the functional role of neuromuscular coherence remains unknown. Furthermore, while coherence analysis provides a unique insight into frequency domain coupling within groups of motoneurons, and between motoneurons and cortical centres, the manner in which coherence varies with the strength and frequency of the input signal and with the characteristics of motor unit discharge has not yet been quantitatively examined. The aim of this study was to examine how well motor unit coherence quantifies the characteristics of shared motoneuron inputs and to compare coherence and synchronization-based measures of correlated motor unit activity. To address these questions, coherence between motor units was examined using a model of the motoneuron pool during the application of common oscillatory inputs across a range of frequencies and amplitudes.
METHODS: Coherence between pairs of simultaneously active motor units was examined in response to shared input signals as the properties of the common inputs were varied. Two types of modulation were applied to the model, a broad-band, random Gaussian signal and a narrow-band common oscillation, bandwidth 2Hz. Full details of the model are provided in (Lowery and Erim, 2004). The magnitude squared coherence and the phase spectra of the point processes representing the motor unit firing times were estimated based on the methods described by Rosenberg et al. (1989). Coherence between any two spike trains was considered significant if both the magnitude squared coherence exceeded the 5 % significance level and the probability of detection exceeded 0.95. Coherence, short-term synchronization and common drive (peak values of the cross-correlation between smoothed and detrended firing rates) between motor units were then compared.
RESULTS: Coherence between the common Gaussian input and the resulting motor unit spike trains decreased with increasing frequency. For a given input strength, for narrow-band inputs the magnitude of the observed coherence decreased similarly, particularly when the frequency of the input exceeded the average motor unit firing rate. Unlike estimates of motor unit synchronization, coherence provided a good approximation of the strength of the shared input at frequencies well below the

average motor unit firing rates. However, with low amplitude, broad-band shared inputs, significant synchronization was observed in cases where coherence was not present. A strong correlation between motor unit synchronization and 15-30 Hz coherence, and between common drive and 0-10 Hz coherence was observed.

CONCLUSIONS: Coherence provides information on the frequency content of shared neural inputs and appears less sensitive to motor unit firing rates than synchronization-based measures. Synchronization may, however, be capable of detecting weak correlations between motor unit discharge times that can not be detected using coherence alone.

Lowery MM and Erim Z. J Comput Neurosci 19: 107-124, 2005. Rosenberg JR, Amjad AM, Breeze P, Brillinger DR and Halliday DM. Prog Biophys Mol Biol 53: 1-31, 1989.

MULTI-CHANNEL MOTOR UNIT NUMBER ESTIMATION: A NOVEL APPROACH

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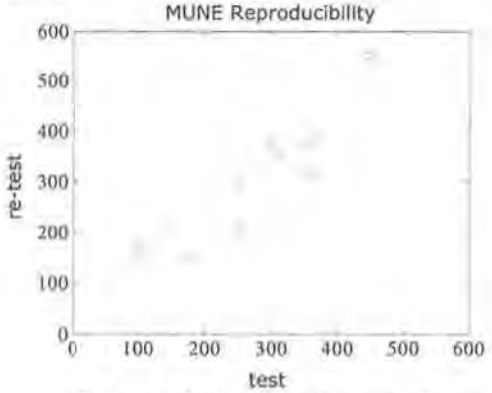
AIMS: Since the introduction of the incremental counting technique by McComas in 1971, several new motor unit number estimation (MUNE) techniques have been introduced. Most techniques try to overcome the problem known as alternation. Alternation occurs when two or more axons have overlapping thresholds for stimulation resulting in a response that can be any summed response of two or more motor units. We introduce a novel MUNE method using high-density surface EMG.

METHODS: High-density surface electrode grids were used to identify and distinguish single motor unit action potentials (MUAPs) based on their combined spatial and temporal profile. A flexible electrode grid (8x15 contacts with 4 mm interelectrode distance) was placed over the thenar muscles. The median nerve was stimulated with increasing current until a first all-or-nothing response became visible. The current was then increased in small steps like in the original incremental counting method. If alternation was visible, the current was kept constant until no new wave shapes occurred. This procedure was applied at four to six different stimulation sites. Analysis of the data was performed off-line using an interactive program. A total of 14 subjects (age 33-60 years old) were measured on two different days by the same investigator. As other techniques the MUNE was calculated as the supra-maximal CMAP divided by the mean single MUAP. We used two different methods. The first one (M1) used only a selected part of the electrodes based on where the CMAP was maximal and averaged those signals to simulate a large electrode. The second method (M2) used all 120 electrode signals and simultaneously divides the CMAPs in all the signals from the respective mean MUAPs.



Test-retest of the number of motor units estimated using all 120 electrodes (M2)

RESULTS: The mean number of motor units on the first visit was 323±128 (M1) and 271±108 (M2). On the second visit the number of motor units was 366±165 (M1) and 294±114 (M2). The number of single motor units used per analysis was on average 22±8 and 25±9 on the first and second visit, respectively. Intra-class correlation coefficient (ICC) was 0.8 for M1 and 0.87 for M2(Figure).

CONCLUSIONS: The number of motor units found is in range with literature data. Both methods have a high ICC. However, the method that includes the signals from all electrodes (M2) has a higher reproducibility. The number of single motor units identified was high compared to other methods. This should increase the accuracy of the estimate. Moreover, the difference between the spatio-temporal profile of the mean single MUAP and CMAP delivers a quantitative measure for how representative the motor unit number estimate is. This way a accuracy measure per measurement is provided.

COHERENCE BETWEEN EEG AND MOTOR UNIT DISCHARGES

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AIMS: Since the original report of coherence between the EEG and surface EMG in the beta band (13-35 Hz), corticomuscular coherence has received much attention from many labs around the world. It has been investigated in different tasks, under varying levels of load compliance, in isometric contractions versus movements, and the results have been interpreted as indicating the coupling between the motor cortex and the motorneuron pool. However, rarely have studies recorded the activity of isolated motor units and almost exclusively rely on inferences drawn from the compound surface EMG signal. The work undertaken in this project represents the first comprehensive study to directly compare motor unit firing patterns to the electrical activity of the motor cortex as reflected by EEG recordings.

METHODS: Multichannel EEG, intramuscular EMG from the target muscle and surface EMG from the target and surrounding muscles, together with joint torque data were collected from healthy subjects. The subjects performed isometric contractions at different force levels using visual feedback in order to investigate the effect of contraction level on the coherence between EEG and motor unit discharges. Two muscles were targeted for motor unit level investigations: the First Dorsal Interosseous and the Biceps Brachii. The choice of a proximal and distal muscle was made due to the known functional and physiological differences associated with the motor control of these muscles groups and in particular to the difference in the strength of cortical projections to the respective motor pools.

RESULTS: Preliminary analysis of the data suggests that even in cases where there is strong corticomuscular coupling as represented by EEG-surface EMG coherence, the coupling is not uniform among the motor units. More explicitly, the EEG-EMG coherence appears to be mediated by coherence between some of the active motor units and the motor cortex, while other motor units display no significant coherence to the EEG signal. Preliminary results also suggest that when motor units exhibit coupling with cortical activity, this coupling is mostly confined to the beta range - the band that was originally reported to display corticomuscular coherence.

T09.P01
MOTOR UNIT CONDUCTION VELOCITY DURING SUSTAINED CONTRACTION OF THE VASTUS MEDIALIS MUSCLE

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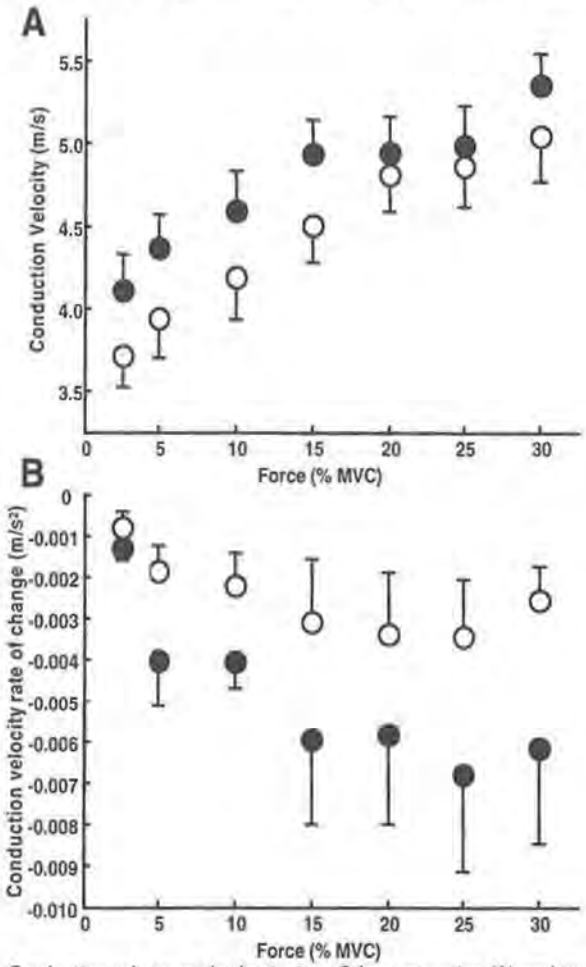
AIMS: The aim of the study was to analyze motor unit conduction velocity at varying force levels of the vastus medialis muscle during sustained contractions.
METHODS: Surface (8-electrode array, 5-mm interelectrode distance) and intramuscular (two wire-electrodes, Teflon coated stainless steel) EMG signals were recorded from the dominant vastus medialis muscle of ten healthy, male subjects (age, mean± SD, 24.2±1.2 yr). The subjects sat comfortably on a chair with the leg 90o flexed and performed seven 180-s long contractions at force levels 2.5%, 5%, 10%, 15%, 20%, 25%, and 30% of the maximal voluntary contraction (MVC) force, in randomized order, which were followed by resting periods of 3, 5, 10, 15, 20, and 25 min, respectively. For each force level, the discharge pattern of the highest threshold motor units was identified from the intramuscular recordings and used as trigger for averaging the multi-channel surface EMG, from which conduction velocity was estimated. Data (mean±SD) were analyzed with ANOVA.
RESULTS: The number of identified motor units was 4.4±2.5 (2.5% MVC), 5.1±3.4 (5% MVC), 5.8±3.0 (10% MVC), 7.6±3.9 (15% MVC), 7.1±3.9 (20% MVC), 8.3±3.5 (25% MVC), and 8.7±4.3 (30% MVC).
Motor unit discharge rate did not depend on force (8.3±0.8 pps). Initial motor unit conduction velocity increased with force ($F=9.5, P<<0.0001$; Figure). It was different between 2.5% MVC and forces >5% MVC, 5% MVC and forces >10% MVC, and 10% MVC with respect to 30% MVC ($P<0.05$). Motor unit conduction velocity rate of change was also affected by force ($F=3.1, P<0.05$; Figure), with 2.5% MVC showing smaller rate of change (in absolute value) than 25% and 30% MVC ($P<0.05$). Initial conduction velocities estimated from the interference surface EMG and from single motor units were positively correlated ($R^2=0.46$; $P<0.0001$), although estimates from the interference EMG were lower (4.44±0.66 m/s) than those from single motor units (4.75±0.56 m/s) ($P<0.05$). Rate of change of conduction velocity at the motor unit level was correlated (and not different) with conduction velocity rate of change estimated from the interference EMG ($R^2=0.18$; $P<0.001$).
CONCLUSIONS: The study investigated motor units with different recruitment thresholds at the same discharge rate and demonstrated that conduction velocity depends on recruitment threshold. It was also shown that, for constant discharge rate, the rate of change of motor unit conduction velocity depends on force.

The Danish Technical Research Council supported this study.



Conduction velocity at the beginning of the contraction (A) and its rate of change during the contraction (B) estimated from single motor units (black circles) and from the interference EMG (empty circles).

T09.P02
INTERNET-BASED RESEARCH RESOURCE FOR EMG DECOMPOSITION: SOFTWARE, DATA, AND MORE

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AIMS: EMG decomposition is a powerful tool for investigating issues related to muscle structure and function, but it is not used as widely as it could be. One reason is the lack of widely available software. Although several labs have developed decomposition programs, there has been little intercommunication, standardization, or dissemination. Another reason is skepticism about accuracy. Since decomposition involves complicated algorithms and possibly human supervision, its results cannot be easily verified. The aim of this project is to promote the wider use and acceptance of EMG decomposition by fostering a greater exchange of discussion, software, and data among investigators in this field.
METHODS: We have obtained NIH funding to establish an internet website to serve as a public forum for discussing issues related to EMG decomposition and for exchanging algorithms, software, and sample EMG signals. The website is intended to be a collaboration tool to aid the work of all researchers interested in EMG decomposition and signal processing. The initial content will include a downloadable version of EMGLAB -an EMG viewer and decomposition program written in Matlab- and several illustrative needle and fine-wire EMG signals. Future content will include standards for storing/sharing signals and annotations (spike firing times and motor unit identities), standards for assessing and reporting decomposition accuracy, EMG experiment databases, EMG signal-processing software, and a discussion forum. The website is planned to be launched in June, 2006.
DISCUSSION: We are seeking the involvement of other investigators, both as users and as contributors, who are interested in advancing the field and practice of EMG decomposition. This involvement will include contributing to the development of standards for exchanging EMG signals and annotations; contributing EMG signals to a public database to illustrate the variety of recording and protocol methodologies that are of interest within the community; reviewing decomposition results of a selected subset of signals to establish a consensus about their true full compositions; helping establish standards for assessing and reporting the accuracy of decomposition results; and helping specify and implement open-source programs and toolboxes for EMG decomposition.

T09.P03
ELECTROMYOGRAPHY ACTIVITY ANALYSES IN THE ORTHOSTATIC POSTURE BEFORE AND AFTER CRYOTHERAPY APPLICATIONS

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AIMS: The real effects of cryotherapy on proprioception have not been established in the literature yet. This work was aimed at evaluating the electrical activity of the tibialis anterior (TA) and the medial gastrocnemius (MG) muscles after the cryotherapy application, to check its effect on different application parts and three different positioning.
METHODS: Fifteen female volunteers participated in this study (24,6±1,45 years old) who were healthy, not physically active, with no history of musculoskeletal pathologies in the lower limbs muscles (LL). The electrodes were placed 2 cm below the motor (M) point of the TA and MG dominant muscle. The reference electrode was placed on the anterior tuberoses of the tibia. The data collect was done in three different conditions, which are repose, on one-leg and on two-leg position, and in different times: before (PRE) and immediately after the ice was taken off (PI). All the recordings were done three times. The ice application (a pack of 1,5 Kg) was done in three different days and it was made of three ice application of 30 minutes, on the plantar surface, the ankle and the gastrocnemius muscle, which were drawn. Right before and after the ice application the skin temperature was collected. The electromyographic signal was acquired by an EMG-1000(Lynn®) data acquisition system, 16 bits resolution, 20-1000 Hz band pass filter and 2.000 Hz sampling frequency. Data processing was carried out through a specific routine using a Matlab® 6.5.1 software for the analysis of the root mean square (RMS). The Wilcoxon test was carried out for the electromyographic and temperature, with 5% of significance for all the analysis.
RESULTS: The temperature alteration was lower when the ice was placed on the plantar surface (PRE 27,78±1,52; PI 18,42±1,49) compared to the gastrocnemius muscle (PRE 29,51±1,20; PI 16,88±1,52) and to the ankle (PRE 29,17±1,31; PI 15,79±2,11). In relation to the repose electromyography, the figures of the RMS increased after the cryotherapy application, except for the ankle application for both muscles. On one-leg position the observed pattern was the increase of the RMS. On the contrary, the decrease of the RMS for the plantar surface and ankle application, and the increase in the gastrocnemius application on two-leg position.

			Plantar surface	Ankle	Muscle
REPOSE	PRÉ	TA	2,07±0,71	1,88±0,41	1,91±0,65
		MG	2,15±0,58	1,83±0,20	2±0,57
	PI	TA	1,91±0,37	1,8±0,16	1,81±0,26
		MG	2,12±0,81	2,05±1,26	3,29±1,36
ONE-LEG	PRÉ	TA	17,83±9,30	15,89±7,84	29,1±10,54
		MG	29,01±17,55	28,6±14,41	29,95±8,77
	PI	TA	22,15±11,86	23,64±9,56	28,37±14,54
		MG	29,52±13,53	25,527±10,91	49,52±18,41
TWO-LEG	PRÉ	TA	7,21±5,48	6,03±3,35	4,8±2,92
		MG	2,73±1,57	2,44±1,24	2,22±0,97
	PI	TA	5,81±4,92	4,22±1,72	8,97±6,14
		MG	2,88±1,36	2,58±1,74	2,45±1,17

CONCLUSIONS: The ice changes the electrical activity of the TA and the MG, depending on the place of the applicatio n and on the collect position.

T09.P04
ANALYSIS OF MOTOR UNIT POTENTIALS IN HEALTHY SUBJECTS

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AIMS: To analysis of motor unit potentials in normal population.
METHODS: 27 females (54%) and 23 males (56%) (total 50 healthy subjects) at a mean age of 41.9±14.1 (the age range of 18-69) were examined. Twenty motor unit potential examples from each of M. Abductor pollicis brevis, M. Biceps and M. Tibialis anterior were collected and amplitude, duration and number of turn parameters were evaluated. The data were compared statistically according to the gender, height and age.
RESULTS: In males the values were as following: in M. Abductor pollicis brevis; amplitude 7.9±1.8 mV (5-11), number of turns 3.6±0.4 (2-5), duration 7.3±0.9 (5.4-9), in M. Biceps; amplitude 7.4±3.0 (3.7-19.5) mV, number of turns 3.2±0.6 (2-5), duration 7.9±0.8 (6-10), in M. Tibialis anterior; amplitude 8.5±1.9 (4.8-12.8) mV, number of turns 3.4±0.6 (2-5), duration 8.5±1.1 (6.6-11.6).
In females the values were as following: in M. Abductor pollicis brevis; amplitude 8.1±2.2 mV (5-12), number of turns 3.6±0.5 (3-5), duration 7.5±0.6 (6.5-9), in M. Biceps; amplitude 6.2±1.5 (3.9-10.9) mV, number of turns 3.1±0.4 (3-4), duration 7.7±0.9 (6-10), in M. Tibialis anterior; amplitude 6.9±1.3 (4.7-9.7) mV, number of turns 3.4±0.4 (3-4), duration 8.2±1.1 (6.2-9.8).
Height was statistically different between males and females (p 0.001). And mean amplitude values were higher in males than females (T test and Mann-Whitney test) (0.005, 0.063). As age increased, mean amplitude values decreased.
CONCLUSIONS: Motor units consist of anterior horn cell, its peripheral axon and muscle fibres innervated by related motor neuron. Hight and age are important parameters affecting amplitude.

T09.P05
THE EFFECT OF GENDER AND AGE ON MOTOR UNIT NUMBER ESTIMATION IN NORMAL POPULATION

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AIMS: To test the MUNE in different age groups in the normal population.
METHODS: This study was done on the healthy volunteers who had not neither peripheral nerve nor systemic/ metabolic disease, and had normal neurological examination. All had normal median and ulnar nerve conduction velocities. One hundred and ten subjects including 58 males and 52 females at a mean age of 38.9±6.6 years were evaluated in 3 age groups. There were 36 volunteers in the age range of 15-30, 44 in the age range of 31-45, and 30 in the age range ≥46 (46-83). Manual incremental method was performed for MUNE. Studies and recordings with a stimulation of 0.1 msec in all subjects were completed.
RESULTS: We did not find a study investigating the association between gender and MUNE scores. Our study showed that gender has no effect on MUNE scores (p=0.472). However, to get more accurate data on this subject, more advanced studies should be needed to investigate the relation between hormonal parameters and MUNE.
CONCLUSIONS: Manual incremental method was used in this study. The investigator decided the sufficiency of stimulus intensity for the following step and enough difference between miniature motor units by himself. Our results revealing quite similar values in standard conditions showed that the method was reliable. These findings support the hypothesis that this method could be used in clinical practice with an alternation factor.

T09.P06
VARIABILITY OF SINGLE MOTOR UNIT ACTIVITY DURING FATIGUING SUSTAINED CONTRACTIONS

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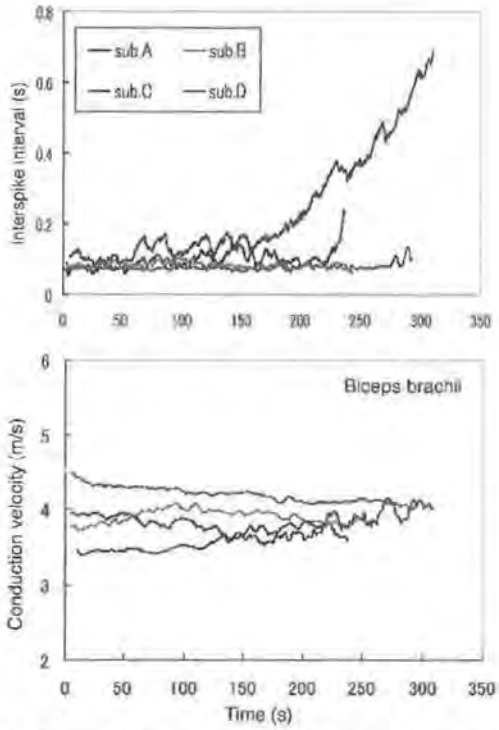
AIMS: It is well known that median power frequency (MDF) of surface EMG shifts to the low-frequency side and the muscle fiber conduction velocity (MFCV) decreases with fatiguing contraction. The surface EMG signals are composed with a number of MUAPs. The purpose of this study is to clarify the variability of single motor unit activity recorded by surface electrode with fatiguing sustained contractions.
METHODS: The experiments were performed on four healthy male adults without signs of neuromuscular disease. Variability of the single MUAP trains were recorded from the biceps brachii and the flexor carpi ulnaris during sustained contraction. Surface EMG signals were picked up with an electrode array consisting of 4 silver wire contacts. The signal was amplified (2000x), band-passed (5-500 Hz) filtered and sampled at 5 kHz. Deriving the single MU was enabled by displaying EMG signals on CRT of the computer and presenting it to the subjects. The variabilities of the MU signal during muscle fatigue were analyzed by MFCV, MDF and interspike intervals. MFCV was computed from the time delay between the same MUAPs identified in two adjacent channels.
RESULTS: Disappearances of single MU activity were observed on the process of muscle fatigue. MFCV of the biceps brachii was within the limits of 3.5-4.5 m/s and a large change was not confirmed. MFCV of the flexor carpi ulnaris was various 2.2-4.6 m/s. MDF of the biceps brachii was a level of 104-138 Hz except that one MU increased by 20 Hz or more. MDF of the flexor carpi ulnaris was various 76-178 Hz. The changes on the muscle fatigue process were not large. The interspike intervals of the biceps brachii were about 100 ms, and it showed to increase before discharge stopping. The interspike intervals of the flexor carpi ulnaris increased before the discharge stopping, too.



Variation of interspike intervals and muscle fiber conduction velocities of single MU activities on the biceps brachii during prolonged isometric fatiguing contractions.

CONCLUSIONS: The results indicate that the substitution of MUs and the decrease of firing rate cause the changes to the surface EMG parameters during muscle fatigue.
Expected variability of single MU with muscle fatigue were not observed. It suggests that the modification in fatigue surface EMG is a recruitment of new motor units which are reviously inactive units with a longer duration and slower velovity of action potential.

T09.P07
MOTOR UNIT SYNCHRONIZATION IN PREVIOUSLY FATIGUED MUSCLE

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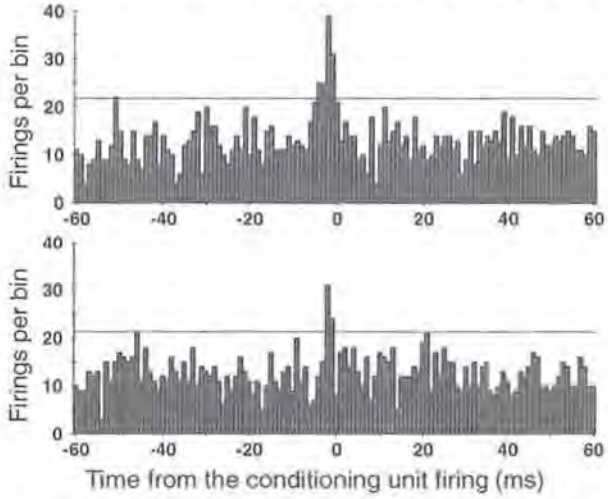
AIMS: The aim was to investigate single motor units (MU) synchronization during a weak sustained contraction of the fatigued extensor carpi radialis muscle. The hypothesis was that synchronization would be pronounced in the continuously active low threshold MUs during a weak contraction, if they have previously been fatigued in a high force contraction. Further, it was expected that the level of synchronisation in the previously fatigued MUs would increase over time during a weak sustained contraction.
METHODS: Ten subjects participated, five males and five females. The subjects were sitting with the forearms horizontally supported. To fatigue the low threshold MUs a five minutes 30% MVC wrist extension was performed against a strain gauge transducer. During this contraction surface EMG was recorded from the right extensor carpi radialis muscle (ECR) and rate of perceived exertion (RPE) was recorded. Immediately after a quadripolar needle electrode was inserted in the ECR muscle and a weak contraction that just lifted the hand from the support was sustained for a five minute period. No feedback of MU activity was given to the subject. Intramuscular EMG was recorded from the ECR muscle and was decomposed into MU action potential trains. Only MUs with continuous discharge pattern in the 5 minutes period were considered for analysis of synchronization. Mean discharge rate and cross-interval histogram was calculated each minute for the MU pairs. The 99% confidence limit for a one sided test of rejecting the null hypothesis of independent behaviour of the MU pair was calculated.
RESULTS: During the 30% MVC contraction a significant increase RPE (3.5 to 8.4 on a scale from 0 to 9) an increase in EMGrms from 23(5) to 41(19)% EMGmax and a decrease in EMGmpf from 102(17) to 81(19) Hz. In four of the ten subjects, motor unit pairs with constant activity over the 5 minutes weak contraction was identified (tree subjects with tree MU and one subject with two MU). A total of 40572 MU discharges were



Cross-interval histogram with peak showing synchronous activity for a motor unit pair. The upper histogram shows the first minute of the hand lift and the lower the fifth minute. Horizontal line represents the 99% confidence limit.

identified, classified and included in the analysis. The mean discharge rate did not change over time for the five minutes, start and end values were 12.9 pps (SD=3.0) and 12.6 pps (SD=2.8). The ten MU pairs for the four subjects all showed significant synchronization during time (cross-interval histogram peaks over the level of significance). No difference in the level of synchronous behaviour of motor units was found between the first and last minute of sustained hand lift.

CONCLUSIONS: Discharge rate in the fatigued ECR was similar to earlier mean value of 12.9 pps (SD=3.3) in the unfatigued ECR during a hand lift. (1) All analysed MU pairs in the fatigued muscle showed syncronized behavior. However, no time wise increase in synchronization was found when activity of the fatigued MUs was sustained for several minutes.

1) Finsen, L., Søgaard, K., Graven-Nielsen, T., & Christensen, H. (2005). Muscle Nerve 31, 242-251

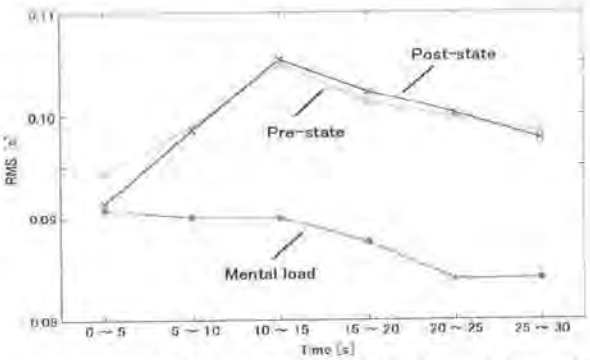


Fig.1 One of results that calculated the RMS of interspike intervals.

T09.P08
INFLUENCE OF MENTAL STRESS ON SINGLE MOTOR UNIT ACTIVITY

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AIMS: The aim of this study is to construct the mental stress evaluation method using surface electromyogram (EMG). The surface EMG signals represent a population of discharging motor units within the muscle. It is known well that MUs is being ruled by the autonomic nerve system. We experimentally explored the influence of the mental stress of single motor unit activity. The surface EMG has been usually used as an index that evaluates the kinetic load of body. We investigated to construct a mental stress evaluation index by analyzing the surface EMG signals of single MU.

METHODS: We recorded the activity of the single MU from the biceps brachii during sustained isometric contraction. The surface EMG signals were picked up with an elecrode array consisting of four silver wire tip contacts. The tips are arrayed at intervals of 5 mm. The diameter of the wire is 0.5 mm. The electrode avoided the innervation zone, and to become parallel to the muscle fiber, was fixed on the skin. The experiments were performed on three healthy male university students. Deriving the single MU was enabled by displaying EMG signals on the display of the computer and presenting them to the subject. The surface EMG of MU was amplified to 2000 times by the bio-amplifier and was recorded to the computer via A/D converter with 2 kHz of sampling frequency. We measured surface EMG of the bicps brachii under two conditions: rest state condition and mental load state condition. The Uchida-Krepelin census was used as a mental load. The subject answered by oral making a mental count of the numeric array presented in the front. The limitation at time to sound the alarm every 10 seconds is installed, and the addtion work is execution continuously. We calculated three characteristics from the surface EMG of the single MUs: muscle fiber conduction velocity (MFCV), the interspike intervals and the variation of the amplitude.

RESULTS: Fig.1 shows one of results that calculated the root mean square of interspike intervals. There were differences of interspike intervals between two conditions. The interspike intervals decreased during calculation load task. It indicate that interspike intervals became narrow by mental loads. The average of amplitude was 50 μV during the calculation load task, and 80 μV during rest condition. However, the tendency for amplitude change to become small by all mental loads was not acquired. MFCV had almost no change at both conditions.

CONCLUSIONS: The results suggest that single MUAP undertakes the influence of a mental stress. We obtained the possibility that the interspike intervals were a useful index as mental stress evaluation.

T09.P09
SURFACE ELECTROMYOGRAPHIC SPIKE FREQUENCY AND MOTOR UNIT FIRING RATES AT DIFFERENT LEVELS OF MAXIMUM CONTRACTION

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AIMS: Surface electromyographic (SEMG) mean spike frequency (MSF) and mean frequency are higly correated (r>0.90) (Gabriel et al., 2001). However, the correlation between MSF and motor unit firing rate (MUFR) has yet to be established. This study assessed the correlational link between between MSF and MUFR.

METHODS: Subjects (N=11) sat in a testing chair designed to isolate the action of the dorsiflexors during an isometric contraction. They completed isometric contractions at 40, 60, 80, and 100% of maximal voluntary contraction (MVC). Force was monitored with a transducer mounted beneath the footplate. The SEMG activity of tibialis anterior (TA) was recorded with Ag/AgCl electrodes. The SEMG signal was amplified (2000x), band-passed (20-500 Hz) filtered and sampled at 2.5 kHz. The MU activity was monitored with a 25-gauge quadrifilar needle electrode placed near the surface electrodes. The MU recordings were band-passed (1 kHz-10 kHz) filtered and sampled at 25.6

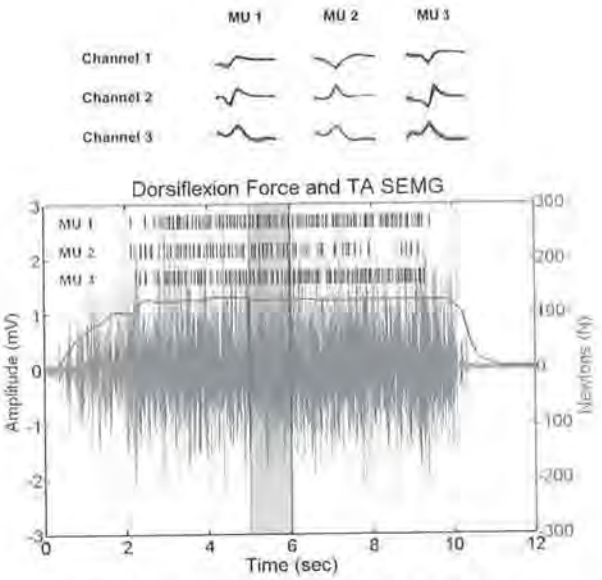

Figure 1: Representative data from one subject.

kHz (Dantec Counterpoint, Dantec Electronic Medicinsk, Skorlunde, Denmark). Regression analysis was performed for MSF and MU firing rate. Results were deemed significant at probability level of less than 0.05.

RESULTS: Representative data are presented in Figure 1. MUFR increased from 16±3 pulses per second (pps) at 40% of MVC to 35±5 pps at 100% of MVC. MSF increased from 142±17 Hz at 40% of MVC to 150±21 Hz at 100% of MVC. The correlation between FR and MSF was r=0.40 for the sample. However, analysis of individual subjects revealed a different picture. Nine subjects had r's that ranged from 0.70 to 0.99. One subject hand an r of 0.30 and another had an r of 0.06.

CONCLUSIONS: For a majority of the sample (9/11) the correlation between MSF and MUFR ranged between good and excellent. For two subjects the correlation was poor. One source of error for these later subjects may be the ability to track the same MUs across the different force levels. MUFR is thought to dominate the lower range of the frequency spectrum of SEMG, and alterations do not have a large impact on changes in mean frequency. We showed that MSF measured from SEMG is indeed reflective of changes in MUFR.

This work was funded by the NSERC of Canada.

Muscle fatigue

RELATIONSHIP BETWEEN MECHANICAL POWER AND FREQUENCY BEHAVIOUR FOR HIGHLY NON STATIONARY SIGNALS USING DISCRETE WAVELET

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AIMS: Short Time Fourier Transform (STFT) and other tools such as time-frequency analysis have been used to analyze fatigue during dynamics conditions. Nowadays, Discrete Wavelet Method (DWM) is currently being used to analyze highly non stationary movements. DWT has the advantage to represent better the information regarding time-frequency analysis than the standard procedures for dynamics contractions. The change in the frequency coefficients, provided by the discrete wavelet transform has been related to changes in the frequency bands (8-16, 16-32 and 32-64 Hz) in presence of fatigue. Therefore, the objective of this research is to associate changes in mechanical power decay with changes in band frequency coefficients using wavelet analysis.
METHODS: Surface EMGs from the vastus medialis muscle were collected during the execution of a Wingate test (n=14 subjects) lasting 30 s approximately. The beginning and the end of each contraction (burst) were automatically calculated by computational algorithm and visually checked to ensure that each burst was completely assessed. Each burst consisted of 256 points. Every five seconds (5, 10, 15, 20, 25 and 30 sec), one representative burst for that time, which coincided with the progressive mechanical power slope, was selected and analyzed by the wavelet method. Intensity coefficients were obtained using the Daubechies number 8 in order to establish an association with the mechanical power decay.

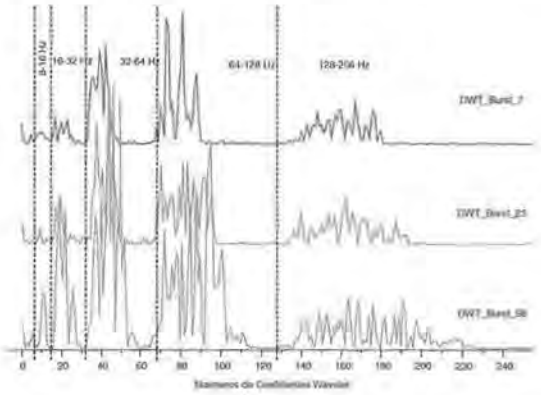

Figure shows the increase of wavelet coefficients in the lowest band frequencies (16-32 and 32-64 Hz)

RESULTS: An increase in the energy coefficients in the frequency bands of 8-16, 16-32, and 32-64 Hz was observed during the test. As long as the test advances, the morphology of the time-frequency matrix is expanded.
CONCLUSIONS: The use of tools such as Discret Wavelet analysis along with mechanical tests helps to evaluate and understand muscle fatigue process in human performance.

CONDUCTION VELOCITY MEASUREMENT IN THE GENIOGLOSSUS MUSCLE DURING FATIGUING CONTRACTIONS

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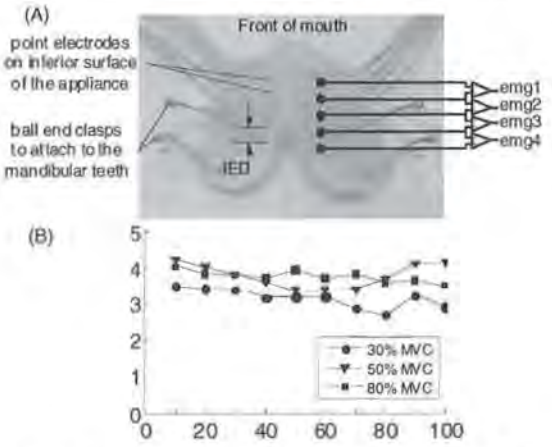
AIMS: The main aim of this study was to measure the conduction velocity (CV) of the genioglossus (GG) muscles during fatiguing contractions, using a custom appliance developed for the measurement of GG surface EMG signals. This technique would be valuable in assessing the fatigability of the GG which may help elucidate the role of peripheral fatigue in this muscle in obstructive sleep apnea syndrome.
METHODS: A custom acrylic appliance, incorporating two linear arrays of point electrodes with an inter-electrode distance (IED) of 3 mm, was made for each of ten healthy subjects (male, 24 ± 2.4 years). The arrays are positioned in contact with the floor of the mouth directly above the GG muscles on either side of the mouth. Subjects were seated at a specially designed rig and pushed their tongue against a lingual force transducer while visual feedback was provided. Fatiguing contractions were performed on different days at three levels of force: 30%, 50% and 80% of the maximum voluntary contraction (MVC). A reference electrode was placed on the forehead and bipolar EMG signals were recorded from each pair of adjacent electrodes on one side of the mouth, with a sampling frequency of 5 kHz. The EMG signals were filtered offline and divided into non-overlapping 500 ms epochs. RMS amplitude and quartile frequencies of the power spectrum were calculated for each epoch. The time shift, $\Delta\tau$, between signals as a result of action potential propagation was estimated using the cross correlation method and the global muscle fibre conduction velocity was estimated using $CV=IED/\Delta\tau$. An automated data screening process identified epochs of poor quality EMG data on the basis of the power spectrum.
RESULTS: Signals from the more posterior electrodes were of higher amplitude and provided better quality EMG signals. RMS amplitude was found to decrease with percentage endurance time. The median frequency of the power spectrum and the estimated CV were found to decrease with percentage endurance time.



(a) The inferior surface of the appliance (b) the change in cv with fatigue at different force levels.

CONCLUSIONS: GG CV can be estimated non-invasively using our appliance design, and the possibility exists for further processing to extract peak CVs which could be helpful in exploring the recruitment strategies in the GG.

DOES LOW AND HIGH FREQUENCY STIMULATION ITSELF CAUSE MUSCLE FATIGUE: IMPLICATION FOR MEASUREMENT

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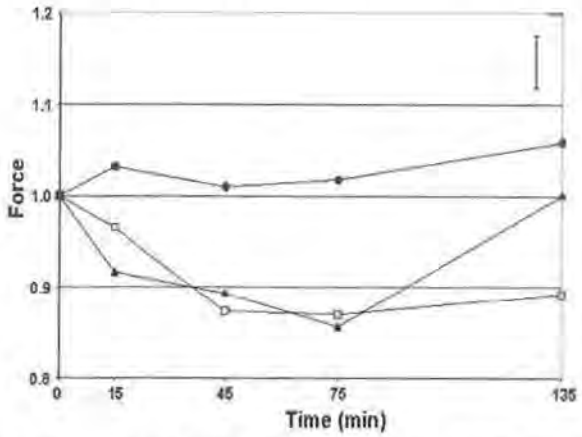
AIMS: A decrease in the ratio of force output at 20:100 Hz stimulation (LFF ratio) has often been used as an index of muscle fatigue. One concern with using the LFF ratio in the context of measuring muscle fatigue at very low force exposures is whether the high-frequency stimulation itself causes muscle fatigue. The objective of this study was to determine whether there were differences in the force response of the muscle between three different electrical stimulation protocols. One protocol involved 2 Hz stimulation of the muscle (Protocol 1) and the other two protocols used different combinations of 2, 20 and 100 Hz stimulation (Protocols 2 and 3). In Protocol 2 the high frequenbcy stimulation followed the muscle twitches and in Protocol 3 the high frequenbcy stimulation proceeded the muscle twitches
METHODS: Using a repeated measures design, ten healthy subjects (6 women, 4 men) ranging in age from 19 to 52 years (31.1 ± 9.4) participated in this study. All subjects were right hand dominant and self-reported to have no current and past history of upper extremity musculoskeletal disorders. In each protocol, the subject's right ring finger flexor digitorum superficialis muscle was stimulated five times: initially (0 minutes) and 15, 45, 75 and 135 minutes thereafter. The force response of the muscle to the electrical stimulation was analyzed for trends with time using RANOVA methods. The order of the protocols was randomized and each protocol was performed on a separate day.
RESULTS: The results showed that the twitch parameters did not change with time in the protocol which consisted of exclusively 2 Hz stimulation (Protocol 1); however, there was a decrease in force response of the muscle in the protocols which included both low (2 Hz) and high (20 and 100 Hz) frequency stimulation indicating these two protocols caused muscle fatigue. In addition, muscle twitch behavior was dependent on the prior stimulation history. When high frequency stimulation immediately preceded muscle twitch measurements (Protocol 2), twitch parameters were altered.
CONCLUSIONS: The electrical stimulation protocols including both low and high frequency stimulation may cause muscle fatigue. The results of this study may be used to design electrical stimulation protocols which will reduce unwanted fatigue effects associated with electrical stimulation.



Changes in FP twitch parameters with respect to time in protocol 1 (circle), protocol 2 (square) and protocol 3 (triangle). Standard error bars are shown in the right upper corner of each graph [N = 10].

DIFFERENTIAL ACTIVATION OF REGIONS WITHIN A SINGLE MUSCLE DURING FATIGUE

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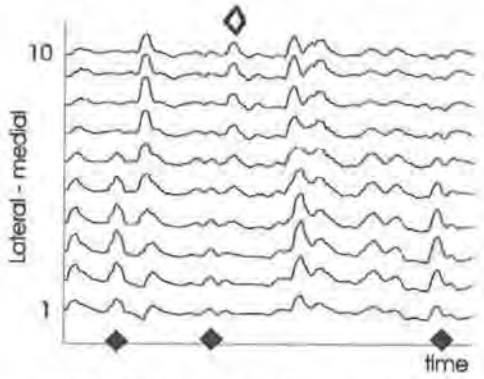
AIMS: Sustained sub-maximal contractions are characterized by an increased EMG level mainly due to recruitment of motor units. The enhanced muscle activation throughout a sustained contraction has been shown to be divergent between synergistic muscles (Hunter et al 2003) and to be spatial uneven within a single muscle (Kleine et al 2000). In addition, activity alterations between synergistic muscles (Kouzaki et al 2002) and individual motor units within a muscle (Westad et al 2003) have been observed. Selective activation of populations of motor units within a muscle, called muscle regions, is observed in isometric tasks of different force direction (Ter Haar Romeny et al 1982), and is thought to afford the use of the best-suited motor units to the given task. The aim of this study was to examine whether different muscle regions can be activated independently or can show activity alternations throughout a sustained contraction until exhaustion.
METHODS: A dynamometer (Biodex), a visual force feedback device (custom made) and a 130-channel multi-channel surface-EMG grid device (Biosemi) placed over the m. biceps brachii were used in the experiment. Thirty-nine male subjects performed a sustained elbow-flexion contraction of the dominant arm at 25% of maximal voluntary contraction until exhaustion. Bipolar root mean square (RMS) of all channels was calculated every 0.5 s. The average RMS of the channels in the fibre direction was computed, resulting in a temporal lateral-medial RMS profile (as in Figure).
RESULTS: Time until exhaustion varied between 2.5 and 18 minutes. Figure illustrates a typical example of differential activation of two regions of the biceps brachii, oriented lateral and medial, respectively. 11 subjects demonstrated such a differential activation between the medial and lateral region of the muscle, where one region was most active at one time segment whereas the other region of the muscle was most active in another time segment. The observed region dependent activation was predominantly observed during the last 25% of the total contraction time.
CONCLUSIONS: The observed selective activation of the two regions within the m. biceps brachii illustrates that parts of a single muscle can be activated independently during a sustained contraction. Such an alternation of activity between muscle regions could have a physiological purpose during a sustained contraction, e.g., shifting blood perfusion between parts of a muscle. The observed differential activation of muscle regions in approximately 28% of the subjects indicates that this aspect is not a direct inherent characteristic of the neuromuscular system.



Average RMS (a.u.) changes during a 2 minute period of 10 rows perpendicular to the fibre direction (lateral-medial), for a biceps brachii muscle during a sustained contraction. Numbers indicate row 1 and 10 respectively. The independent activation of the two regions are illustrated with ◊ when only the medial region is active, and ♦ when only the lateral region is active

ASSESSMENT OF MYOELECTRIC MANIFESTATIONS OF FATIGUE IN THE VASTUS LATERALIS AND MEDIALIS MUSCLES

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AIMS: Although the muscles of the quadriceps group work together to achieve a common function, there is evidence in the literature to suggest that they can be differentiated based on anatomy, function and physiology. The purpose of this study was to determine whether surface electromyography (sEMG) for the assessment of myoelectric manifestations of muscle fatigue is capable of detecting differences between the vastus lateralis and medialis muscles which are consistent with the results of biopsy studies.
METHODS: Nine volunteer subjects (five female) aged between 20 and 44 years (mean 31.3, SD 8.6 years) participated in this study. Surface EMG signals were recorded from the vastus medialis longus (VML), vastus medialis obliquus (VMO) and vastus lateralis (VL) muscles in single differential configuration using linear adhesive electrode arrays (four contacts, 10 mm apart) during isometric knee extension contractions at 60% and 80% of the maximum voluntary contraction (MVC). The intial value and rate of change of the mean frequency (MNF), average rectified value (ARV), and conduction velocity (CV) of the EMG signal were calculated.
RESULTS: For the sustained isometric knee extension contraction at 80% MVC, the initial value of CV was greater in VL and VML compared to VMO ($p=0.02$ and $p=0.007$ respectively) and the initial value of MNF was greater in VL compared to VML ($p=0.02$). In addition, a significantly greater rate of change of MNF was present for VL compared to VML ($p=0.015$) and the normalized rate of change for MNF was greater in VL compared to both VML ($p=0.038$) and VMO ($p=0.05$).
CONCLUSIONS: The VML, VMO and VL demonstrate differences in EMG variable estimates during sustained isometric knee extension contractions which are consistent with the results of previous biopsy studies.
The VL muscle, which has been characterized by a large proportion of fast twitch muscle fibers, demonstrates a motor unit pool which is more fatigable than the VML muscle, the least fatigable among the three muscles.
When comparing across the three muscles, the most significant differences were identified between VL and VML which are most different histochemically. These findings support the premise that surface EMG signals and their time course during fatiguing isometric contractions may be useful to non-invasively describe characteristics of the vasti muscles and may be used to distinguish between muscles with large differences in fiber type distribution.

Muscle	Type I (%)	Type II (%)
VML	59.5 (155)	43.9 (100)
VMO	39.5 (103)	51.7 (118)
VL	38.4 (100)	64.2 (146)

Fiber type composition for the vastus medialis longus (VML), vastus medialis obliquus (VMO), and vastus lateralis (VL). The percent differences with respect to the minimum value are indicated in brackets. Data for VML and VMO are obtained from the results of Travnik L [J Anat, 1995], while data for VL are presented as a mean value obtained from the work of Johnson MA [J Neurol Sci, 1973] and Tesch PA [J Appl Physiol, 1984].

PHYSIOLOGICAL CHARACTERISTICS OF MOTOR UNITS IN THE BRACHIORADIALIS MUSCLE ACROSS FATIGUING LOW-LEVEL ISOMETRIC CONTRACTIONS

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AIMS: The purpose of this study was to determine (i) if decomposition-based quantitative electromyography (DQEMG) could detect changes in motor unit potential (MUP) morphology and motor unit (MU) firing pattern statistics associated with muscle fatigue, (ii) if any detected changes are correlated with surface electromyographic (SEMG) signs of fatigue, and (iii) if significant fatigue-dependent changes are repeatable within individuals.
METHODS: Mean MU firing rates and the morphology of MUPs detected using needle and surface electrodes during constant-torque isometric contractions held until exhaustion were investigated in the brachioradialis (BR) muscle in ten healthy volunteers (mean age = 28.6 yr, SD ± 3.9). Time dependant changes were investigated using an analysis of variance with normalized time as a main effect. Partial correlation coefficients were computed using a repeated measures analysis of covariance to determine if changes in MU firing rates, needle-detected MUPs and surface-detected MUPs (SMUPs) were related to changes in SEMG signal amplitude and frequency parameters. Intra-class correlation coefficients (ICCs) were used to determine the within-subject repeatability of changes in MU firing rates, and MUP and SMUP parameters.
RESULTS: Significant decreases in mean MU firing rates were found along with significant increases in various duration and area related parameters in both MUPs and SMUPs across the fatiguing contraction. The SEMG signal demonstrated the expected changes with fatigue: an increase in amplitude and a decrease in frequency content. SEMG amplitude was significantly positively correlated with SMUP peak-to-peak voltage ($r=0.85$, $p<0.05$), and SMUP area ($r=0.86$, $p<0.05$). Mean power frequency was significantly negatively correlated with SMUP negative peak duration ($r=-0.74$, $p<0.05$). The significant time dependent changes were reliably observed (ICCs were 0.94 for MUP peak to peak amplitude, 0.97 for MUP area and 0.95 for MUP area to amplitude ratio, 0.95 for SMUP peak-to-peak voltage, 0.83 for SMUP area, 0.99 for SMUP negative peak amplitude and 0.88 for SMUP negative peak area).
CONCLUSION: The decreases in mean MU firing rates measured along with the increases in amplitude, duration and area parameters of MUPs and SMUPs and their partial correlation with SEMG amplitude during submaximal fatiguing contractions of the BR, suggest that recruitment is a main cause of increased SEMG amplitude parameters with fatigue. We conclude that DQEMG can be effectively and reliably used to detect changes in physiological characteristics of MUs that accompany fatigue.

CENTRAL MOTOR CONTROL FAILURE IN FIBROMYALGIA SYNDROME: A SEMG ASSESSMENT OF TREATMENT EFFECTIVENESS

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AIMS: Main feature of fibromyalgia syndrome (FMS) is the presence of abnormal perception of muscle fatigue. The aims of the work are: 1) to non-invasively assess the functional condition of fatigued muscles in FMS patients by means of advanced techniques in surface EMG recording and processing; 2) to compare findings between a group of FMS patients and a healthy control group; 3) to assess if the differences (if any) between the

two groups can be associated to a pathological alteration of the sensory-motor *central* control strategies or to *peripheral* changes in the neuromuscular system, and 4) to assess if treatments can reverse the FMS-induced pattern of myoelectric manifestations of fatigue. These issues were investigated during two successive protocols.

METHODS: Eight female patients (FMS, 55.6±13.6 years, mean±SD) and eight healthy female volunteers (HLT, 50.3±9.3 years, mean±SD) were studied in the first protocol. Myoelectric signals were detected from the biceps brachii muscle using a linear array of 16 electrodes. Electrically elicited and voluntary contractions were performed by the subjects in the experimental session. Fourteen volunteer subjects (TRT, 12 female and 2 male, aged 45.3±11.1 years, mean±SD) participated in the second protocol. A transdermal system for the rate-controlled systemic delivery of buprenorphine (TDS-B) has been used. Active treatment lasted nine days with the application of a new patch of TDS-B every three days. Surface EMG measurements were collected before and after the treatment.

Maximal voluntary contraction (MVC), initial values and rate of change of the mean spectral frequency (MNF), average rectified value (ARV), conduction velocity (CV), and motor unit action potential conduction velocity distributions (mean±SD and skewness) were estimated to assess whether significant differences existed between the two groups.

RESULTS: MVCs were found not statistically different in the two groups. Lower myoelectric manifestations of fatigue (described by CV and MNF normalized rate of changes) were observed in FBR (-0.074±0.052%/s and -0.29±0.16%/s, respectively) with respect to HLT (-0.196±0.133%/s and -0.66±0.34%/s, respectively) and by a concomitant higher CV distribution mean values and skewnesses in the FBR than in the HLT group. Results from electrically elicited contractions did not differ between the two groups. MNF rate of change and normalized rate of change were found statistically different in TRT with respect to HLT before the treatment, whereas difference disappeared at the end of the protocol.

CONCLUSIONS: Surface EMG was found able to distinguish FBR with respect to HLT on the basis of muscle behaviour in response to fatiguing exercise. Differences between the two groups were found only in voluntary contractions, hence related to a central motor control failure rather than to a muscle membrane alteration. An altered sensory input of both nociceptive and muscle load can explain the observed altered motor pattern behaviour in FBR. Finally the use of buprenorphine recovers surface EMG manifestations of fatigue to levels comparable with those of healthy subjects.

PRELIMINARY DEVELOPMENT OF A NEW EMG-BASED TEST TO ASSESS THE CAPACITY OF BACK MUSCLES

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AIMS: Back muscle capacity is impaired in chronic low back pain (CLBP) patients but no motivation-free test exists to measure it. The aims of this study were to assess the reliability and criterion validity of EMG indices sensitive to back muscle strength and absolute endurance. We also tested the possibility of using regression equations to predict these outcomes using anthropometric and EMG variables as predictors.

METHODS: Healthy subjects (43 males and 31 females; age: 20-55 yrs) performed 3 maximal voluntary contractions (MVC) and a fatigue test while standing in a static dynamometer measuring L5/S1 moments [1]. Surface EMG signals were collected from 4 pairs of back muscles [1]. The fatigue test, assessing absolute endurance (90 Nm load), consisted of repeating an 8-s cycle extension task (1.5 s ramp to reach 90 Nm + 5 s plateau at 90 Nm + 1.5 s rest). For all subjects, a familiarization session (MVCs + 10 min. fatigue test) was followed (2-7 days later) by a test session (MVCs + fatigue test to exhaustion or 60 min). To assess reliability (data from sessions 1 and 3), 19 males and 11 females performed a 3rd session (2 weeks after session 2). *Strength* was defined as the peak MVC while our endurance criterion was defined as the time to reach exhaustion (*Tend*) during the fatigue test. The EMG signals corresponding to each plateau (3 to 5 s of data) were processed in the time-frequency domain [2] to compute instantaneous mean frequency (IMF) and in the temporal domain to compute RMS values. Only the first 5 and 10 min of EMG data were used for females and males, respectively. The slopes of the IMF time-series (*IMFslp*) were averaged bilaterally and retained as the EMG index of fatigue for each muscle group. In the temporal domain, the RMS time-series were used to compute EMG indices presumably sensitive to variable load sharing between back muscle synergists [3].

RESULTS: The Pearson correlations between the different EMG indices and *Tend* (criterion validity) were used to select a subset of EMG indices (r = -0,33 to 0,69). A subset of EMG indices from the temporal domain were also particularly correlated to *Strength* (r=-0,72 to -0,81). The reliabilities of the retained EMG indices ranged from moderate to excellent (intraclass correlation coefficient: 0.40 to 0.83) for the 4 back muscles located medially. Gender-specific multiple regression equations were developed, using the retained EMG indices from the 4 medial muscles, to predict *Tend* (males : R^2=0,76, relative error=9%; females: R^2=0,70, error=17%) and *Strength* (males: R^2=0,72, error=9%; females: R^2=0,25, error=13%). Spectral and temporal domain EMG indices were both included in these equations.

CONCLUSIONS: It appears possible to estimate the capacity of back muscles (strength and absolute endurance) using an intermittent and time-limited (submaximal) fatigue task. Contrary to previous EMG-based tests involving short-duration sustained contractions at a high relative load (>70% MVC), intermittent contractions at a moderate absolute load (90 Nm) were used, thus eliminating MVCs. This test has the potential to better infer the back muscle capacities relative to more realistic occupational tasks because more specific muscle fatigue mechanisms are involved.

[1] Larivière C, et al. (2003) *J Electromyogr Kinesiol* 13:305-318
[2] von Tscharner V. (2000) *J Electromyogr Kinesiol* 10:433-445
[3] van Dieen JH, et al. (1993) *Eur J Appl Physiol* 66:70-75

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BACK MUSCLE FORCE, ENDURANCE AND FATIGABILITY IN RECURRENT LBP CASES FROM NURSING AND ADMINISTRATIVE PROFESSIONS

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AIMS: In chronic LBP patients an increased fatigability of back muscles compared to healthy was found [1,2]. Since a fatigued muscle lacks the possibility to exert the required force, altered coordination pattern or reduced segmental stability may be the consequence. Nevertheless, it remains unclear whether decreased capacity of trunk muscles causes LBP, or whether fear avoidance behaviour and disuse in LBP cases lead to a reduced functional capacity of the back muscles.

The aim of the present study was to compare the functional capacity of the back extensor muscles in terms of maximum voluntary contraction (MVC), endurance, and measures of fatigue derived from surface EMG measurements between elderly female worker with and without non-specific recurrent low back pain.

METHODS: 64 female worker with recurrent LBP as well as age matched controls (mean age of 51.6±4.5 years, mean height of 164.4±6.1 cm and mean weight of 63.6±10.9 kg) were selected from nursing (n=36) and administrative (n=28) professions.

Recurrent LBP was defined based on the Nordic questionnaire as having reported low back pain on 8-30 or more days during the last 12 month. Maximum voluntary isometric contraction (MVC) in trunk extension was measured in standing position. The endurance in trunk extension was measured by a modified Sorensen test with simultaneous recording of the surface EMG over M. multifidus. Linear electrode arrays with 5 mm inter-electrode distance [3] were bilaterally positioned between a point three cm lateral of the spinal process of L5 and the spinal process of L3 after cleaning and gently abrading the skin. Signals were band-pass filtered between 10 and 400 Hz, analogue to digital converted (16 bit) at a sampling rate of 2048 Hz and stored for offline analysis.

RESULTS: After visual scrutiny for sufficient quality to allow spectral analysis, EMG recordings from 39 (61%) out of the 64 subjects were further analysed.

MVC and endurance of the trunk extensor muscles did not differ between LBP cases and healthy controls, but when comparing the two professions, endurance in trunk extension tended to be smaller ($p=0.08$) in administrative officers. MPF slopes were -0.11±0.17 Hz s^{-1} (right) and -0.13±0.17 Hz s^{-1} (left) and no significant group or side differences were present.

CONCLUSIONS: The present study focused on back muscle function in subjects suffering from recurrent, non disabling LBP. The expected reduction in back muscle capacity in LBP cases could not be observed. This lets us conclude that in recurrent LBP, signs of deconditioning are not yet present.

In the present study, the MPF slopes were much smaller than those reported by Choorevits [4] who used a slightly different test setting. It has to be considered that depending on the task, the multifidus muscle can act as an actor or as a stabilizer and thus may show different fatigue behaviour. Only about 60% of the EMG recordings showed sufficient quality for further analysis. This highlights the special challenge associated with EMG applications in the lower back for clinical studies.

[1] Biering-Sorensen -F. Physical measurements as risk indicators for low-back trouble over a one-year period. Spine 1984; 9 106-119

[2] Mayer TG, Smith SS, Kondraske G, et al. Quantification of lumbar function. Part 3: Preliminary data on isokinetic torso rotation testing with myoelectric spectral analysis in normal and low-back pain subjects. Spine 1985; 10 912-20

[3] Merletti R, Farina D and Gazzoni M. The linear electrode array: a useful tool with many applications. J Electromyogr Kinesiol 2003; 13 37-47

[4] Coorevits PL, Danneels LA, Ramon H, et al. Statistical modelling of fatigue-related electromyographic median frequency characteristics of back and hip muscles during a standardized isometric back extension test. J Electromyogr Kinesiol 2005; 15 444-51

ELECTROMYOGRAPHY STUDY ABOUT BUCCINATOR AND MASSETER MUSCLES IN SUBJECTS ANGLE CLASS I AND III

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This study aimed to assess and compare the pattern carried out by buccinator muscle compared to masseter muscle in volunteers Angle Class I and III, during mastication cycle. Two groups of subjects were studied: 16 volunteers Class I and 16 Class III, age range between 18 and 40 years old. Electromyographical analysis of referred muscles was proceeded by use of Myosystem I electromyographer, and for data processing and analysis Matlab® software (version 5.3) was used. Due muscle size were used as to transducers, Medtrace® passive bipolar surface electrodes with intereletrode distance 0.5 cm (Dimitrova et al, 2003), joined to Lynx® preamplifiers to create a circuit corresponding to a differential electrode. Variance Analysis , Tukey Tests were applied to compare means and Student-test t obtained from 2 independent samples . Variables were analyzed qualitatively and quantitatively. Qualitative analysis was completed comparing the curve itself related to Angle Class I and Class III volunteers . As for quantitative analysis, statements providing support to qualitative findings were analyzed, namely: the ratio between inactive period of Root Mean Square - RMS and active period of RMS for each muscle; maximum instant - IMAX and active period duration - ON mastication cycle about classes and muscles. Qualitatively EMG activity for buccinator muscle during mastication cycle was clearly drawn, although correspondence of cyclic activities to masseter muscle did not always exhibit the same proportions. In volunteers Class I masseter muscle exhibited two clearly marked periods, of activity and inactivity. On its turn, buccinator muscle carried out a similar pattern during masseter muscle jaw elevation phase, even reaching its peak at the same moment, and ceasing its activity in wide correspondence to jaw depression. However after 0,24 ms of inactivity it slightly re-started activity during masseter muscle inactivity period. On the other hand, Class III volunteers exhibited activity pattern of masseter muscle similar to those of Class I volunteers, showing balanced periods of activity and inactivity. Buccinator muscle, however, exhibited completely distinct pattern, with periods of long duration and desynchronized activation, completely out of pace with masseter muscle cycles. The result of ratio between inactive period and active period - RIA for masseter muscle was 7% in Class I volunteers, and 9% in Class III volunteers, proving the existence of two similar periods, of inactivity and activity. Regarding buccinator muscle, however, it was 50% in Class I volunteers, and 90% in Class III volunteers partially similar, marking off the existence of an inactivity period activity period in volunteers Class I more similar volunteers Class III. To analyze IMAX and ON variables variation coefficient - CV values were calculated in relation to maximum peak and mean. The variation coefficient related to maximum peak was used as a reference for investigations, since it shows the smallest dispersion index. Activity IMAX between the muscles of Class I and III volunteers did not show significant differences. Regarding variable ON, buccinator muscle in Class I and III volunteers exhibited a significantly larger active period comparing to masseter muscle.

T10.P01
COMPARISON OF THE LEVEL OF FATIGUE BETWEEN DIFFERENT MUSCLE GROUPS USING EMG SPECTRAL ESTIMATES AND THE BORG CR-10 SCALE

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AIMS: The slope of the relationship between EMG spectral estimates and time is often used to contrast the fatigue of different muscles. However, the validity of such a practice is unknown. The purpose of this study was to determine whether between-muscle differences substantiated with EMG spectral estimates is at least corroborated by a subjective criterion of muscle fatigue (concurrent validity).
METHODS: Thirty-one healthy subjects (15 males and 16 females; Age: 32, SD: 10 yr) performed trunk flexion-extension cycles (25° flexion to 15° extension) in a Biodex dynamometer (isotonic mode) until exhaustion. The load was applied only during the extension phase and determined theoretically as twice the L5/S1 moment produced by the upper body mass when positioned horizontally (range: 67 to 128 Nm at L5/S1). The EMG signals were recorded bilaterally using eight pairs of electrodes placed on the lower back and thoracic muscles (spinal level L4 and T10, respectively) as well as on the gluteus maximus and biceps femoris. Immediately after exhaustion, the subjects were asked to rate the fatigue of each muscle group using a Borg CR-10 scale [1] combined with a drawing of the body representing the four areas.
The EMG signal corresponding to the middle 20°-portion of each extension contraction was processed in the time-frequency domain [2] to compute the instantaneous mean frequency (IMF) of each muscle group. The slopes of the IMF time-series (*IMFslp*) were retained as the EMG index. The Borg ratings were also divided by the time to exhaustion (*BORGslp*) to correct for the time when muscle fatigue was rated.
RESULTS: The time to exhaustion values ranged between 1.5 and 20 min (mean: 6 min). Borg ratings varied with the muscle group and ranged between 1 and 9. A significant difference (ANOVA) was obtained between muscle groups for both EMG (*IMFslp*) and subjective (*BORGslp*) criteria of muscle fatigue. Post hoc analyses revealed that the lower back muscles had the most negative *IMFslp* (more fatigue). The *BORGslp* results partially corroborated this finding with a more positive *BORGslp* (more fatigue) observed for the lower back but the difference reached significance only with the upper back (T10). The lower and upper back contrast was further studied to reveal the link between the EMG and subjective criteria of fatigue. There was an association (Pearson correlation), between *IMFslp* and *BORGslp* for the lower back ($r = -0.70$; $p=0.000$) but not for the upper back ($r = -0.01$; $p=0.950$). In addition, the slope of this association (linear regression) was significantly different (t-test for difference between slopes) between the lower (slope: -0.31; CI = -0.42 : -0.19) and upper back (slope: 0.00; CI = -0.14 : 0.13) muscles.
CONCLUSIONS: Although interesting, the agreement of both *IMFslp* and *BORGslp* to identify the lower back muscles to be more fatigued than the other muscle groups might be coincidental. However, the correlation analyses and, more importantly, the significantly different slope values depicting the relationship of *IMFslp* and *BORGslp* of two muscles (lower and upper back muscles) known to fatigue at a different rate (based on previous analyses) is more convincing. These results support the use of EMG spectral estimates of muscle fatigue to compare different muscle groups.

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[2] von Tscharner V. (2000) J Electromyogr Kinesiol 10:433-445

Funded by the Occupational Health and Safety Research Institute Robert-Sauvé (IRSST).

T10.P02
ELECTROMYOGRAPHIC STUDY IN ERECTOR SPINAE, RECTUS ABDOMINIS, GLUTAEOUS MAXIMUS AND RECTUS FEMURIS MUSCLES, IN STANDING AND STATIC POSTURE

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INTRODUCTION: The internal forces of muscles can be sufficiently big is answer have for external load is get equilibrium and stabilize spine, probably this forces muscle can be responsable is most of compressible forces and of sliding over spine and, consequently, is responsable for resulting in the lesions of the back, extreme this load become when. When one suddenly imposed is load on body, they will answer fastly is stabilize body.
AIMS: Observe the loads associates application with in position of body because it vanishes authors relate that they occur lesions in the region lumbar with much frequency, mainly in workers that are directly exposed for these loads, in the static or dynamic postures.
METHODS: The electromyographic study in *erector spinae*, *rectus abdominis*, *glutaeous maximus* and *rectus femoris* muscles was accomplished in female volunteers from 18 have 27 years old, previously selected. The muscles electric activities was gotten with surface electrodes, in standing and static posture, with the parallels and horizontal upper limbs with load on her hands. The load was equivalent have 5% and 10% of body weight of each volunteer. The volunteers remained first with their elbows in total extension and then were kept in 90° with semi-flexing of *glenohumeralia* articulation and finally with maximum flexing of *glenohumeralia* articulation and elbows with the load near body.
RESULTS: The statistical study it was used analysis of variance have causality experiments in blocks with factorial scheme, and complemented with Tukey's test with significance level of 5%. According have results, electric activity of *erector spinae* and *glutaeous maximus* muscles was statistically greater than other muscles in position where the load was in horizontal distance greatest relating have body, when the upper limbs were parallels in same level of shoulders and with elbows in total extension. The *rectus abdominis* and *rectus femoris* present minor electric activity but also statistically significant.
DISCUSSION: Therefore it was observed that it's better have maintain the loads near body possible, in order have decrease fatigues and avoid injuries in lumbar region that are common in some professions.
CONCLUSION: In this study it was clearly observed influence of the load and distance there is over studied musculature associated with standing erect posture.

T10.P03
ELECTROMYOGRAPHY EVALUATION OF OCCLUSAL SPLINT INFLUENCE ON ORBICULARIS ORIS IN DENTURE-WEARING SUBJECTS WITH TEMPOROMANDIBULAR DYSFUNCTION

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AIMS: The occlusal splint constitutes a resource frequently used on temporomandibular dysfunction (TMD) treatment, including the denture-wearing patients. Considering the active participation of the lips in all functions of the stomatognathic system, the aim of this study was to verify the influence of occlusal splints on electromyography activity (EMG) of two portions - upper (OBU) and lower (OBL) - of orbicularis oris muscle, during the yogurt suction.
METHODS: EMG was accomplished before and 70 days after the use of these splints, in 8 edentulous denture-wearing patients

and that had signs and symptoms of TMD. The myoeletric signs were recorded by a 16 channel signal conditioner with 12 bits dynamic band resolution (*Lynx Eletronics), Butterworth-type band pass filter (20-500Hz) with gain of 100 times, and A/D converter board placed inside of an Electrostatic cage of Faraday. The signs were displayed through by Aqdados Software installed in an Ibm-pc 486 DX2, that showed simultaneus presentation of used channels, each one with frequency of sampling of 1000 Hz. The signal was caught by Ag/AgCl surface electrodes (Medi Trace). The EMG sign was processed by the Matlab® Software (version 5.3) and the averages of the non-normalized amplitude envoltories (NNA) were statistically analyzed using Mann-Whitney test ($p< 0,05$).

RESULTS: The NNA values found on pre-treatment was 60,11±4.28 and 86,15±6.15 μV and in the post-treatment was 106,0±4.80 and 103,71±3.83 μV for the portions OBU and OBL respectively. The verified statistical difference was highly significant ($p<0,0001$) when compared the same muscular portion before and after use of the splints.

CONCLUSIONS: The results of this study, on those experimental conditions used, may conclude that the use of occlusal splints promoted a significant increase of the electric activity of the orbicularis oris muscle.

T10.P04
CLINICAL AND ELETROMYOGRAPHIC EVALUATION OF THE PLANAS APPLIANCE IN PATIENTS WITH TEMPORO-MANDIBULAR DYSFUNCTION

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The Temporo-Mandibular Dysfunction (TMD) is an articular desease with multifatorial causes that appear in very people, especially when exposed in high stress, like policemen. The mean of present study was investigate, in policemen, clinical and eletromyographic, the behavior of the temporal, masseter and suprahioideos muscles in patients with TMD, before and after use of different occlusal devices, during four weeks. Thirty volunteers with myogenic TMD were selected, divided random in three groups, with no occlusal device (control group), with Planas Indirect Tracks (PIT group) and with the Michigan's bite plates (M group). The eletromyographics results were significant ($p<0,05$) in the anterior portion of the left temporal muscle during the maximal voluntary contraction (MVC) of the PIT group. However, in the clinical exam regarding the reduction of the sensibility palpation, the PIT group was significant ($p<0,05$) in the left temporal, centre fibers of the right temporal and right masseter muscles. In the M group it was observed significant in the anterior fibers of the right and left temporal muscles. In Analogical Visual Scale of pain, the M group there was significant ($p<0,05$) and, in the PIT group there was strong significant ($p<0,001$) in the reduction of the pain. Concludes that PIT showed better performance in the remission of the muscular sintomatology in the DTMs.

T10.P05
SEMG AND FUNCTIONAL MAXILLARY ORTHOPEDICS: MUSCLE REST RECORD BEFORE AND AFTER 8 MINUTES OF APPLIANCE USE

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AIMS: The purpose of this work is to present the results of SEMG record before and after use for 8 minutes of Functional Maxxilary Orthopedic Appliance; it will be showed as follows. For yeas it was a deal for researchers around the world, the possibility of record the muscle rest with minimum alteration in μV, closer to zero as possible (Basmajian & De Lucca,1985). Using our simple method proposition, we had these kinds of signals. The diminish of these RMS signals after the use for 8 minutes of FMO Appliance were expected,based on the work presented in past ISEK Meeting (Boston,2004). But at this time, more than that results, it was obtained a diminished register of rest record after the use of this kind of appliance. The results indicate that the rest registration of these muscles, diminished, going closer to zero.

MATERIALS: Electromyograph LYNX Electronics, model BIO EMG1000, software AqDAnalysis (Lynx Electronics), software Lynx BioInspector (Lynx electronics- Low-pass filter:100 Hz, High-pass filter:20 Hz); frequency:2000 Hz,time:1,024 seconds),notebook HP-Compaq NX9005 (PentiumIV,Intel 650 Hz, HD 80GB,RAM 512 Mb), surface electrodes (self-adhesive Ag/AgCl, NORAXON DUAL ELECTRODE,272,USA), surface electrodes (KENDALL-MEDITRACE,Ag/AgCl), ambient electromagnetic isolation.

METHOD: Skin was cleaned with 70% alcohol solution and cotton. Patient position: seated on plastic chair, hands on legs, without head set, feet on the ground rubber carpet, natural light, eyes open. For isometric record,the patient was voice oriented; for rest,without any orientation; for D.A. position: in rest,without orientation; in isometric record, with voice orientation ("bite,bite,hold,hold; relax). All the records started and finished in rest following the recommendations established in SENIAM.

RESULTS: The comparison between records before (diagnosis) and after 8 minutes of use of FMOA showed a decrease of signals that varied with malocclusion, biotype, rotational type, kind of Functional Maxillary Orthopedic Appliance.

CONCLUSIONS: It should be possible to conclude that this kind of treatment, after 8 minutes of use, can aletr the way of muscular tissue respond to functional stimuli gave by them based on a good diagnosis.

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T10.P06
SEMG AND FUNCTIONAL MAXILLARY ORTHOPEDICS: RESULTS FOR DIAGNOSIS

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AIMS: The purpose of this work is to present some results of the use SEMG as a tool for diagnosis in Functional Maxillary Orthopedics. The use of SEMG in diagnosis for Functional Orthopedic treatment is relatively recent. Recognized as specialty in Dentistry in Brazil recently (2000), the Functional Orthopedic is going to its space. Based on the fact that muscle tissue has differentiation before osseous, understanding its function and value for the correct development of the Stomatognatic System is basic for the clinical application of Wolff's Law, Moss's Functional Matrix Concept, Plana's Development Laws traduced in Functional Orthopedic. As a protocol, we used to use surface EMG of both sides of Mm. masseter, anterior temporalis and suprahyoids to determine the electromyograms in rest, isometric contraction and deglutition of 10 ml of water. The findings showed that if the patient has its mastigatory function developed preferently by one side (Minimal Vertical Dimension Side), the electromyograms of this side is clearly more loaded than the opposite. The comparison of the RMS values from both sides from all muscles shows us this difference, confirming previous findings. The knowledge of these findings, for Functional Maxillary Orthopedics rae fundamental specially to understand what's the way of masticatory function, and supported on this plus other diagnosis examinations (anamnesis, Xray, cephalometrics, casts, photographs, tapes), it's possible to have a view for diagnosis and treatment of malloclusions using the tools that Functional Maxillary Orthopedics can offer for us.
MATERIALS: Electromyograph LYNX Electronics, model BIO EMG1000, software AqDAnalysis (Lynx Electronics), software Lynx BioInspector (Lynx electronics-Low-pass filter: 100 hz, High-pass filter: 20Hz); frequency: 2000Hz, time: 1,024 seconds), notebook HP-Compaq NX9005 (PentiumIV, Intel 650 Hz, HD 80GB, RAM 512 Mb), surface electrodes (self-adhesive Ag/AgCl, NORAXON DUAL ELECTRODE, 272, USA), surface electrodes (KENDALL-MEDITRACE, Ag/AgCl), ambient electromagnetic isolation.
METHOD: Skin was cleaned with 70% alcohol solution and cotton. Patient position: seated on plastic chair, hands on legs, without head set, feet on the ground rubber carpet, natural light, eyes open. For isometric record, the patient was voice oriented; for rest, without any orientation; for D.A. position: in rest, without orientation; in isometric record, with voice orientation ("bite, bite, hold, hold; relax). All the records started and finished in rest following the recommendations established in SENIAM.
RESULTS: Functional alterations in masseter amd anterior temporal muscles were seemed: number of functional units activated, graphic differences viewed in rest, isometric and deglutition records.
CONCLUSIONS: The SEMG can be an important tool to be used in diagnosis for treatment of functional alterations of neuromuscular part of the stomatognatic system.

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T10.P07
SEMG AND FUNCTIONAL MAXILLARY ORTHOPEDICS: THE RESULTS AFTER OBTAINING DETERMINED AREA (D.A.) DENTAL CONTACT

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AIMS: The purpose of this work is to present some clinical and SEMG results before (diagnosis) and after obtaining Determined Area (D.A.) dental contact; this is a revolutionary clinical concept enounced by Simões (Brazil) in 1978; it establishes that the ideal incisor dental contact must be between the incisors first third part. Recording bilateral surface EMG of Mm Masseter, anterior Temporalis and Suprahyoids as one diagnosis tool and after obtained D.A. it was found that: -most of the functional orthopedics treatments diminished the electromyograms records in RMS at rest, isometric contraction and deglutition; - the variation was obtained for all muscles; - it was found an equilibration of bilateral muscle contraction in all of them; - the results are directly dependent of: byotipe (Bimler), type of malocclusion, rotational type (Lavergne-Petrovic), protrusion movement classification (Simões), kind of FMO Appliance was indicated to use (bioplastic or bioelastic).
MATERIALS: Electromyograph LYNX Electronics, model BIO EMG1000, software AqDAnalysis (Lynx Electronics), software Lynx BioInspector (Lynx electronics-Low-pass filter: 100 hz, High-pass filter: 20Hz); frequency: 2000Hz, time: 1,024 seconds), notebook HP-Compaq NX9005 (PentiumIV, Intel 650 Hz, HD 80GB, RAM 512 Mb), surface electrodes (self-adhesive Ag/AgCl, NORAXON DUAL ELECTRODE, 272, USA), surface electrodes (KENDALL-MEDITRACE, Ag/AgCl), ambient electromagnetic isolation.
METHOD: Skin was cleaned with 70% alcohol solution and cotton. Patient position: seated on plastic chair, hands on legs, without head set, feet on the ground rubber carpet, natural light, eyes open. For isometric record, the patient was voice oriented; for rest, without any orientation; for D.A. position: in rest, without orientation; in isometric record, with voice orientation ("bite, bite, hold, hold; relax). All the records started and finished in rest following the recommendations established in SENIAM.
RESULTS: Rest and isometric registration showed an interesting difference after gained D.A. position, were all of records diminished the pregistration, as quality and quantitative point of view.
CONCLUSIONS: Based on the fact that D.A. position is a goal for Functional Maxillary Orthopedic treatment and the register in rest and isometric condition diminished, it should be possible to understand that it is a good goal for malocclusion treatment by the functional point of view.

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T10.P08
THE RELATIONSHIP BETWEEN STERNOCLEIDOMASTOID ACTIVITY AND NECK DISABILITY INDEX IN CHRONIC PAIN PARTICIPANTS (PILOT STUDY)

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AIMS: The aim of this study was to investigate a possible correlation between neck disability (NDI) scores and the slope of fatigue (normalised) in sternocleidomastoid muscles in participants with chronic neck pain of both traumatic and non-traumatic onset.
METHOD: 10 participants (5 non-traumatic onset, chronic neck pain (NTNP), 5 traumatic onset, whiplash associated disorder grade-II, chronic neck pain (WAD-II)) performed isometric head raises until the position could no longer be maintained. Each participant repeated this exercise on three separate occasions. SEMG was recorded, bilaterally, from the sternocleidomastoid muscles (1). Subjective neck disability was measured using the NDI questionnaire, completed before each exercise. The linear regression coefficient of the normalised slope of the median frequency was correlated with the NDI scores.
RESULTS: Initial analysis showed a relationship between the slope of fatigue and NDI in WAD-II participants, (see Table 1).
CONCLUSION: The initial analysis shows a statistically significant relationship between the slope of fatigue and NDI scores in whiplash participants. This is not reflected in the NTNP participants. The results may be due to a change in use of the SCM muscles in whiplash participants, who may recruit superficial muscles to a more postural role to avoid activation of the painful deep muscles. NDI scores have been shown as a predictor for the outcome of whiplash injury (2).

	Spearman's Rho Test of fatigue slope and NDI scores. Correlation coefficient (*R*) and p-value (*p*).								
Group	Side	Session 1		Session 2		Session		Mean	
		R	*p*	*R*	*p*	*R*	*p*	*R*	*p*
NTNP	Left	0.500	0.391	-0.100	0.873	-0.410	0.493	-0.100	0.873
NTNP	Right	-0.300	0.624	-0.700	0.188	-0.500	0.391	-0.500	0.391
WAD-II	Left	0.872	0.054	0.900*	0.037	0.700	0.188	0.900*	0.037
WAD-II	Right	0.872	0.054	0.700	0.188	0.900*	0.037	1.000**	0.001

Table 1. Rho scores of linear regression coefficients of the slope of fatigue and NDI scores. *Significant at 0.05 level ** Significant at 0.01 level.

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T10.P09
ANALYSIS OF ELECTROMYOGRAPHIC FATIGUE THRESHOLD AT DIFFERENT RESISTED ELBOW FLEXION EXERCISES

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AIMS: Weightlifting training has been widely used not only to obtain of better athletic condition, but also for a better esthetic shape. These trainings cause neural and morphological changes over time, with increases on the muscular force output in the first eight weeks, as well as on the electromyographic (EMG) activity. In this context the purpose of this study was to identify and to compare the electromyographic fatigue threshold (EMG_{FT}) for the right biceps brachii muscle during dynamic contractions, performed in three different resistance exercises: biceps curl (BC); adapted biceps curl (ABC) in which compensatory shoulder flexion movements were atenuated; and preacher biceps curl (PBC).
METHODS: Ten healthy and untrained in resistance exercises males performed these three exercises above cited, one exercise per day in randomized sequence. In each day test, after three 5-seconds maximum isometric voluntary contractions of elbow flexion at 90° the subjects performed four sets of one minute, with loads at 25%, 30%, 35% and 40% of 1-RM in randomized sequence. The rhythm to perform these exercises was determined by a digital metronome calibrated at 40bpm. Between each set there was a 10 minutes of rest. The EMG data collection were performed using sampling frequency of 4000 Hz, gain of 1000, high pass filter of 20 Hz and low pass filter of 500 Hz. Root mean square (RMS) of EMG signal was analyzed during 250 ms when the elbow reached 90° in the concentric phase. For each set performed the RMS values obtained were correlated with time on each load by linear regression analysis. The respective slopes were correlated with correspondent load to determine the EMG_{FT} (DeVRIES et al., 1982; MORITANI et al., 1982; MATSUMOTO et al., 1991). Load level effects on slope values for each exercise, as well as the exercise effect on slope values for each load level was analized by means Kruskal-Wallis analysis of variance. The ANOVA was applied for EMG_{FT} values to determine the exercise effects. The significance level used was $p<0.05$.
RESULTS: Slope values (Figure 1) presented no significant load effect for BC, ABC and PBC. The exercise effect for each load level presented significant difference at 25% between BC and PBC. The EMG_{FT} values for BC (31.67±6.64% 1-RM), ABC (27.53 ±6.98% 1-RM) and PBC (25.48±8.71% 1-RM) analysis showed no significant differences between these exercises.
CONCLUSIONS: The execution of biceps curl, adapted biceps, and preacher biceps curl reveals no important alterations in biceps brachii activation with the increase of load level, as well as about different positioning to perform elbow flexion resistance exercises, what is reflected in similar EMG_{FT} values.

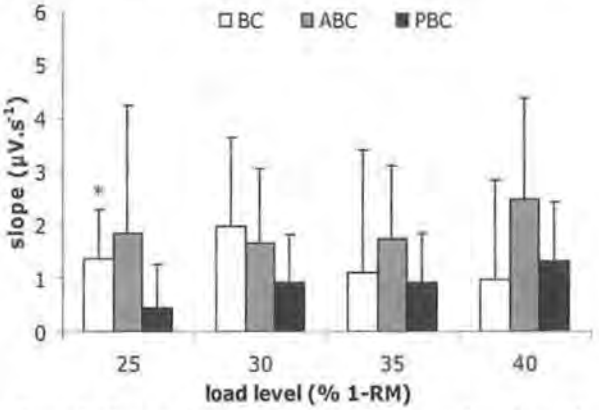

Figure 1. Mean and standard deviation for slope values obtained during biceps curl (BC), adaptated biceps curl (ABC) and preacher biceps curl (PBC).
**Significant difference in relation to PBC in 25% 1-RM.*

T10.P10
EFFECT OF A SHORT PERIOD ENDURANCE TRAINING ON THE ELECTROMYOGRAPHIC FATIGUE THRESHOLD

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AIMS: The muscular fatigue is one of the causes for spine muscular-skeletal lesions, and its analysis may prevent lumbar lesions promoted by the sports practice, daily life activities and especially labor tasks. So, to evaluate the muscular conditions biomechanically become extremely important. The present study has as objective to verify the effect of short period endurance training on the endurance time and on the electromyographic fatigue threshold (EMG_{FT}) of the longuissimus thoracis muscle.
METHODS: Twenty healthy male subjects volunteered for this study. They were divided into two groups: control group (CG: n=10) and training group (TG: n=10). The electromyography signals were sampled at 1kHz using surface electrodes placed bilaterally over the longissimus thoracis muscle at the level L1 (Roy; De Luca; Casavant, 1989) with an inter-electrode distance of 2 cm. A gain of 1000, a high pass filter at 20Hz and low pass filter at 500Hz was also used. The task consisted in to perform isometric contractions at 30%, 40%, 50% and 60% of maximal voluntary contraction, obtained one week before the task, randomly in the MA ISOSTATION 2001 with the trunk at 45° of flexion. In this equipment a load cell and a display were coupled to promote a visual feedback to the subjects. After, to the TG, it was accomplished the training protocol adopted from Moffroid et al., (1993), what consisted of four weeks endurance training, accomplished three times per week. In each isometric contraction were obtained the endurance time and the electromyographic signal to determine the EMG_{FT}. These variables were obtained pre and post training to both groups. To the statistical analysis it was used the ANOVA.
RESULTS: The results have shown a load effect on the endurance time to both groups pre and post training, where as high are the load as low are the endurance time. Comparing groups there is no difference between them in the pre training, showing the homogeneity of groups. The comparison between endurance time pre TG and post TG and between post CG and post TG has shown significant difference. The mean values and the standard deviations of the EMG_{FT} are: 38.01±5.54 to pre CG; 34.75±8.33 to post CG; 37.99±9.56 to pre TG; 36.48±7.50 to post TG.
No significant difference was found between groups and between pre and post training. The increase in the endurance time may be associated to changes in several mechanical parameters, but this change was not accompanied by measurable physiologic changes, (ie, EMG_{FT}). A possible reason for these results can be the increase in the ability of other muscle not evaluated in the present study as the hamstrings or gluteus.
CONCLUSIONS: The training protocol has improved the physical ability, once the endurance time presented higher values post training, however it was not strong enough to change the EMG_{FT} probably because of the training characteristics. In this sense more vigorously and longer period of training should be performed.

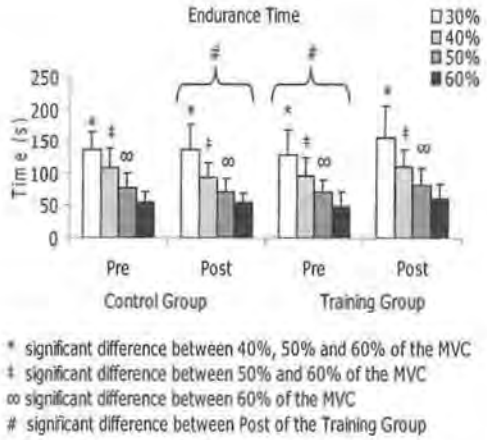

Figure 1: Mean values and standard deviations of the endurance time pre and post training to CG and TG.

T10.P11
EVALUATION OF MUSCLE FATIGUE DURING SKIING BY EMG SIGNALS SELECTED WITH KNEE JOINT ANGLES

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AIMS: We have evaluated physical activity in terms of muscle activity during exercise and autonomic nervous activity during rest. In this report, we focused on muscular fatigue by selecting active and passive phases of muscle activity with the knee angles. The purpose of this study is to demonstrate that muscle fatigue during skiing at each turn can be easily evaluated at selected muscle activity phases.
METHODS: The experiment was held at the 4,000-m downhill ski course, where the maximum slope was about 20 degree and the average slope was about 14 degree. The number of turns was about 24 times at one slide from the top of the hill to the bottom. Total trials were 11 for one day. Actually, we measured surface EMG signals at the tibialis anterior (TA) and the vastus lateralis (VL) muscles during skiing with the knee angles, using a wearable unit with a PDA.
For estimating muscular fatigue, we calculated the Mean Power Frequency (MPF) of surface EMG signals at each turn, selecting the intervals with the knee joint angles. Selected significant intervals included active phases and passive phases. The active phase was defined in the interval of stretching the knee joint, and the passive phase was defined in the interval of bending the knee joint, at each turn.
RESULTS: Figure 1 shows the averages and standard deviations of MPF at the VL with respect to turn in active phases (upper) and in passive phases (lower). The MPF decreased in both active and passive phases up to 10 turns from the beginning conspicuously. At the beginning of skiing, MPF was about 140

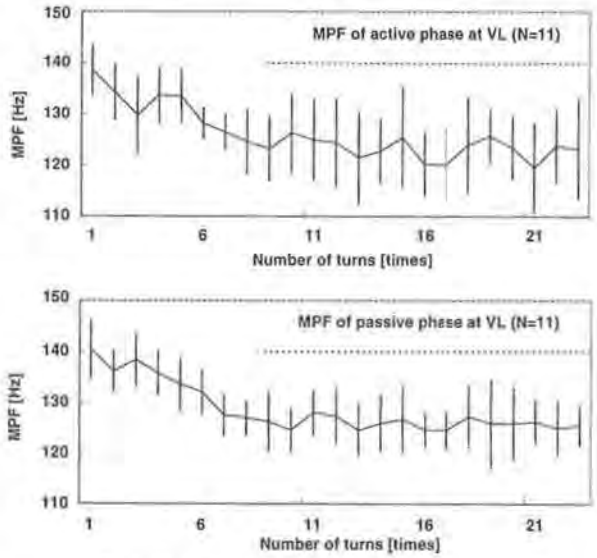

Fig. 1: Changing average of MPF at every turn

Hz, then it decreased about 125 Hz at the 10th turn. It became a plateau state afterwards, and the standard deviations became large. Comparing the trend of MPF change in active phases with that in passive phases, the standard deviation in active phases was larger than that in passive phases. Besides, the decreasing line of passive phases was smoother than that of active phases.
CONCLUSIONS: Comparing to previous results without selecting phases during skiing, the proposed approach was able to obtain a more remarkable characteristic than ever for evaluating muscular fatigue during skiing.

T10.P12
ELECTROMYOGRAPHY OF THE RESPIRATORY MUSCLES AND A PHERIPERAL MUSCLE DURING AN ERGOMECTRIC TEST

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AIMS: The aim of this paper was to study the electromyographic activity of the respiratory muscles (sternocleidomastoid, external intercostal and diaphragm) and a pheriperal muscle (rectus femuralis) during an ergomectric test.
METHODS: All the twelve volunteers which participated in this experiment were sedentary and non-smokers, and had no present or previous cardiorespiratory pathologies. The respiratory muscle electrical activity was obtained by the signal acquisition module (EMG1000, Lynks, Brazil), with impedance of 10^9 ohms, resolution of 16 bits and input range of ±1v. Four active bipolar surface electrode consisting of two Ag/AgCl bars with a gain of 20x, CMRR >100dB were used. The channels were adjusted to a gain of 1000x with band pass filter with cut-off frequency at 20-1000 Hz and sampling frequency of 2000 Hz. To study the sternocleidomastoid muscle the electrode was placed between the jaw angle and the ear lobe in the muscle belly 4 cm below the mastoid process. A second electrode was placed in the third intercostals space 3 cm parasternal to analyze the external intercostals muscle. The third electrode was placed on the 7th intercostals space on the nipple line to investigate the diaphragm muscle, and the fourth electrode was placed in the rectus femuralis. The thigh was measured and the result divided by 5 leading to a constant X-cm. The motor point was found and the electrode was placed 2X-cm away from it. A ground electrode was coated with a layer of conductive gel and fixed on the sternum. The ergomectric test was performed in a Monark cycle ergometer. An initial warm-up was done, followed by a 25-watt increment every two minutes until exhaustion, after which a two-minute recovery took place using the same initial load. The Friedman test followed by the post hoc the Dunn test were used to study the behaviors of the peak normalized RMS.
RESULTS: Only at the peak of the test significant differences were observed for the sternocleidomastoid and intercostals muscles. No differences were detected for the diaphragm, while for the rectus femuralis such differences were seen at all test times when compared with the rest (Figure 1).
CONCLUSIONS: In the ergomectric test the males recruited the accessories and intercostals muscles only at maximum effort. As the diaphragm has a rhythmic pattern it might have remained unchanged. An increase in the activation patterns of the rectus femoralis was probably observed due to the load imposed to the lower limbs.

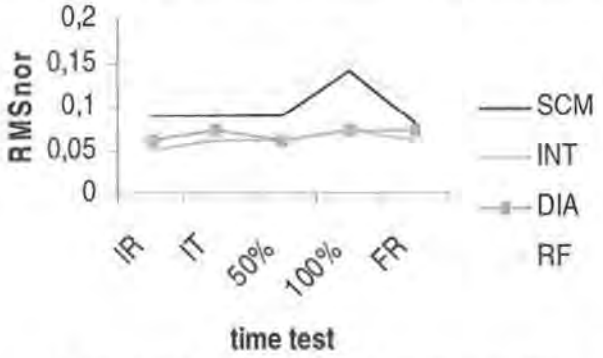

Figure 1: RMS Behaviors of all studied muscles during the ergometer test, SCM: sternocleidomastoid; INT: intercostals; DIA: diaphragm; RF: rectus femuralis; IR initial rest; IT: initial test; 50%: 50% of the test; 100%: 100% of the test; FR: final rest

T10.P13
ELECTROMYOGRAPHIC EVALUATION OF CARRIERS PATIENTS OF TEMPOROMANDIBULAR DISORDER SUBMITTED TO INTERDISCIPLINAR TREATMENT - CLINICAL CASES

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The Temporomandibular Disorders (TMD) are characterized by several signs and symptoms, among with pain and changes in the electromyographic activity of the masticatory muscles. The modern therapeutics for TMD emphasize the supression or reduction of symptoms and, if possible, prevention of the same ones, restoring the balance of the skull-cervical system. The purpose of this paper was to evaluate the electromyographic activity in two patients submitted to Negrelli Neuromasticatory Manipulative Facilitation technique associated with interventions of the Functional Maxillary Orthopedics, Phonoaudiology (myotheraphy) and Psychology (brief psychotherapy), proving the effectiveness of the interdisciplinar approach in the modification of the mandibular biomechanics. Therapeutical procedures as plate and occlusal adjustment, orthodontic treatment, biofeedback training, classic massage and transcutaneous stimulation demonstrated decrease of the myoelectric activity of the masticatory muscles studied. The attainment of the radiograph, oral followed the norms praised for the FOP/UNICAMP. The electromyographic evaluation of the masseter muscle, temporal, anterior and posterior portion and suprahyoid had been gotten in the postural position, habitual chew and maximun intercuspation. Surface electrodes had been used (Ag/AgCl, MEDITRACE), connected to the electromyograph MIOSYSTEM I, PROSECON Inc., frequency: 1000 Hz, filter pass band: 20-500 Hz. The present study demonstrated the efficiency of the electromyographic analysis to monitor changes in the pattern of the muscular activity, in differents phases of the treatment process. It still demonstrated that the Negrelli Neuromasticatory Manipulative Facilitation technique associated with interventions of the Functional Maxillary Ortophedics, Phonoaudiology and Psychology can be efficient in the decrease of the myoelectric activity and relief from pain in carriers patients of temporomandibular disorder (TMD).

Key words: electromyography, TMD, masticatory muscles, interdisciplinar approach.

T10.P14
RADIOGRAPHIC STUDY OF THE CRANIOMANDIBULAR BIOMECHANIC QUANTIFIED BY THE SURFACE ELECTROMYOGRAPY OF MASTICATORY MUSCLES- REPORT CASES

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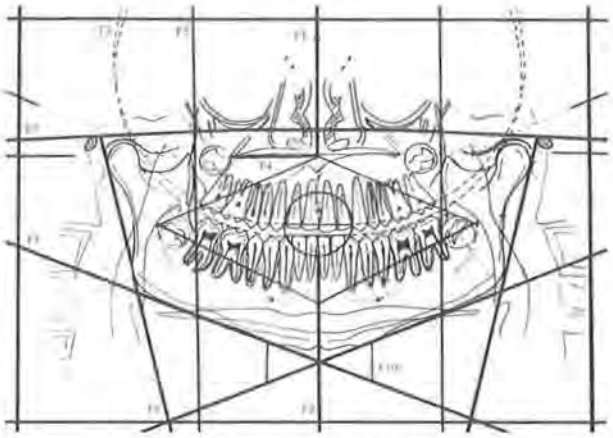
AIMS: This study intends to demonstrate the objective relationship between the Panoramic radiographics images, analyzed by the Hyperbolic line of Brazil (Cheida et al., 2005)

and the teleradiography based in the line of Rocabado (1994) and the electromiographics lines of the masticatory muscles of the craniomandibular biomechanics by the study of the muscles forces levers, in four report cases.
METHOD: The radiographics images followed the Piracicaba Dentistry College(UNICAMP) standards. Electromyography results of the Mm masséter, temporal, anterior and posterior portions and supra-hyoids were obtained at the postural position, habitual chewing and maximum intercuspation. It was used surface electrodes, of the Ag/AgCl, trade mark Meditrace, connected to the Myosistem I equipment, trade mark Prosecon Ltda, frequency of 1000 Hz, digital filter with a band pass of 20-500 Hz.
RESULTS: The results confirm the objective relationship between the radiographics images and the electromyographics results, that make possible a better diagnosis precision of the temporomandibular disfunctions.
Keywords: Eletromyography, diagnosis, panoramic radiograph, teradiography



Brazil's Hiperbolic Line. F= Factor

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T10.P15
COMPARISON OF WAVELET AND FOURIER ANALYSES OF EMG SIGNALS TO ASSESS MUSCLE FATIGUE DURING DYNAMIC CONTRACTIONS

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AIMS: The purpose of this study was to compare the validity and reliability of two processing methods to compute EMG indices of fatigue using either the Fast Fourier transform (FFT) or the Wavelet transform (WAV).
METHODS: Thirthy-one healthy subjects (15 males and 16 females) performed trunk flexion-extension (25° to -15°) cycles on a Biodex dynamometer (isotonic mode) until exhaustion. The load was determined theoretically as twice the L5/S1 moment produced by the trunk mass when at horizontal (load range: 67 to 128 Nm at L5/S1). To assess reliability, 10 subjects performed the entire protocol a second time two weeks later. EMG signals were recorded bilaterally with twelve pairs of electrodes placed, on the back muscles at L4, L3, L1 and T10, as well as on the Gluteus maximus and Biceps femoris. The endurance time (T_{end}) was used as criterion (gold standard) to determine fatigue. At the end of the task, the subjects were asked to rate their perceived fatigue using a Borg CR-10 scale. The EMG signal corresponding to the middle portion (15° to -5°) of each extension contraction was processed using FFT and WAV [1] to compute the median frequency (*MF*) and the instantaneous mean frequency (*IMF*), respectively. In addition, the power of the EMG signal contained within 8 frequency bands (range: 27 to 364 Hz, as defined in [2]) was also estimated from both FFT ($FFTB_i$; i= band number) and WAV ($WAVB_i$) analyses. Linear regression was applied to each time-series and the slope values (EMG fatigue indices) were normalized to their intercept (*NMFslp*, *NIMFslp*, $NFFTBslp_i$, $NWAVBslp_i$) and averaged bilaterally. The Borg ratings were also divided by the T_{end} to exhaustion (*BORGslp*) to correct for the time when muscle fatigue was rated.
RESULTS: The reliability of both criteria of fatigue (*BORGslp* and T_{end}) was moderate to excellent with Intra-class correlation (ICC) of 0.69 (Standard error of measurement; SEM: 35%) and ICC of 0.92 (SEM: 22%), respectively. *NMFslp* and *NIMFslp* were not significantly different from each other, had a comparable association (Pearson's r range: 0.40 to 62) with our criteria of fatigue (*BORGslp* and T_{end}), showed similar reliability results (ICC range: 0.40 to 0.84) and this for all muscle groups. The analyses performed in the 8 frequency bands showed comparable results, with exception for the high-frequency range (242 to 364 Hz) where the reliability of the $NWAVBslp_i$ was better than $NFFTBslp_i$ for the lower back muscles (L4).
CONCLUSIONS: This study demonstrated that the assessment of back muscle fatigue during dynamic contractions was possible using both Wavelet and Fourier analyses. The fact that no systematic differences were observed on FFT and WAV processing might be attributed to the averaging effect of linear regression. This reduced the detrimental effect of complex non-stationarities observed in dynamic contractions which generally affects spectral quantities estimated from FFT [1].

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RA Da Silva (PhD student) and this project are both supported by the Occupational Health and Safety Research Institute Robert-Sauvé (IRSST).

T10.P16
IS THERE ANY CHANGE ON SHOULDER AND SCAPULA PROPRIOCEPTION AFTER FATIGUE OF THE INTERNAL ROTATORS?

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AIMS: To investigate alterations of shoulder and scapula proprioception between pre- and post-fatigue of the internal rotator.
METHODS: Twenty young healthy collegiate volunteers, mean age of 20 years, participated in this study. Four electromagnetic tracking sensors (Flock of Birds, Ascension Technology Corp., VT, USA) with six degree of freedom were palced on the subject's dominant side include acromion process of scapula, thoracic spinal process (C7/T1), the sternum, the upper arm and superior angle of scapula. Active repositioning test of the shoulder joint and scapula to assess the function proprioception were conducted before and after fatigue of the internal rotators. Participants were asked to wear an eye-cover and positioned in sitting. For active repositioning test of the shoulder, subjects elevated the shoulder in the scapula plane to a pre-determined position, 30°, 60° and 120° as measured by an inclinometer. In addition, for the active repositioning test of the scapula, the scapula was moved to pre-

determined mid-position of elevation, depression, protraction and retraction. Muscle fatigue was carried out with the subject side lied on floor and repeatedly performing internal rotation, at first using s dumb-bells at 80% of maximum force measure and decreased to 40% gradually. To ensure all subjects were fatigue, the fatigue protocol was conducted until maximum muscle force is below 50% confirmed. The distance change (mm) in anterior/posterior and in vertical direction between the superior angle of scapula and the thoracic spinal process was used to determine scapula movement of protraction/retraction and elevation/depression, respectively.

RESULTS: The results indicate that fatigue of the shoulder internal rotators did not affect shoulder and scapula joint proprioception. (Table 1, $p>0.05$).

Shoulder (degree)	Before		After		F value	*p* value
	Mean	SD	Mean	SD		
Elevation 30°	8.4	7.4	6.9	6.0	2.59	0.13
Elevation 60°	8.6	6.9	8.2	6.0	0.25	0.62
Elevation 120°	7.5	5.3	6.0	4.0	2.65	0.12
Scapula (mm)	Mean	SD	Mean	SD	F value	*p* value
Depression	2.0	1.7	1.8	1.5	0.27	0.60
Elevation	1.8	1.6	2.2	2.5	0.82	0.78
Protraction	0.9	0.9	1.1	0.9	0.49	0.50
Retraction	1.2	1.3	0.9	0.8	1.18	0.29

Table 1 Active repositioning difference in shoulder elevation and scapula movements.

CONCLUSIONS: Fatigue of internal rotators have no effect on proprioceptive perception in shoulder elevation and scapula movements possibly due to the use of different muscle groups. This suggest that perhap other factors apart from fatigue may contribute to shoulder injury, for instance in baseball pitchers.

T10.P17
EMERGING STRATEGIES FOR FATIGUE ESTIMATION DURING DYNAMIC MUSCLE CONTRACTIONS

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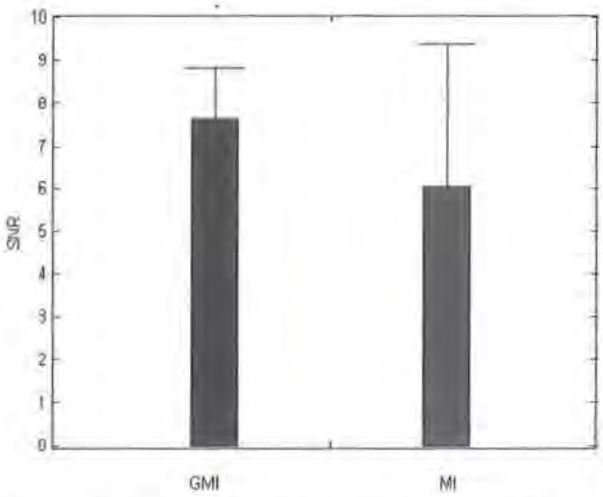
The Ability to assess localized muscle fatigue is of great importance to fields such as rehabilitation, ergonomics and sports medicine. A new index known as the Mapping Index of Fatigue (MI) was developed by MacIsaac which has shown promise in tracking fatigue under dynamic conidtions. Using a fully connected multi-layer perceptron network, a mapping function is tuned to generate an estimate of fatigue from a segment of myoelectric signal (MES), given four time-domain features derived from the segment. The drawback to this approach is that it requires a set of baseline data from each participant in order to train the network. A proposed solution is to develop a generic network which, once trained, could be used to estimate fatigue from the data of any participant.

Building on the success of MI, the Generic Mapping Index (GMI) also uses a fully connected multi-layer perceptron network whose inputs are the same four time-domain features. GMI differs from MI in how the network is trained. Rather than training independent networks for each individual, a single network is trained from baseline data of many participants. It is hypothesized that a diverse training set will allow the network to identify a more general progression of fatigue rather than a particular manifestation from any one participant.

Figure 1 shows the signal to noise ratio (SNR) of GMI and MI estimates from random muscle contractions, averaged across 5 participants. For GMI, the network was trained using data from 4 completely different participants under static, cyclic and random muscle contraction conditions.

Based on a statistical analysis of these preliminary results, GMI performs as well as MI (ANOVA, $\alpha=0.05$, $p>0.6$). These results are very encouraging and further tuning and testing of the algorithm is the focus of ongoing research.



SNR of fatigue estimates under random contractions.

T10.P18
ELECTROMYOGRAPHIC RESPONSE OF THE STERNOCLEIDOMASTOID AND TRAPEZIUS MUSCLES IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS

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AIMS: The purpose of this study was to evaluate the association between bilateral electromyographic (EMG) activity of the sternocleidomastoid (SCM) and trapezius muscles in patients with temporomandibular disorder (TMD) and healthy control subjects.

METHODS: The EMG activity was assessed in fifteen healthy subjects (26.2±4.42 years) and eleven patients with TMD (25.91±3.59) during rest and maximum voluntary clenching of the teeth. Normalised root mean square (nRMS) values were

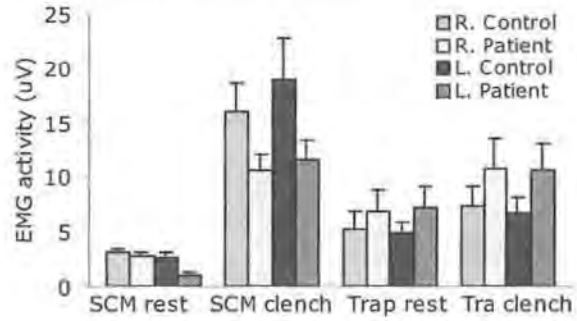

Fig. 1; Mean±SE of the EMG activity of SCM and Trapezius muscles in control and patient groups during rest and maximum voluntary clenching (R, right side; L, left side).

calculated for the SCM and trapezius muscles. Subjects attended three testing sessions over non-consecutive days and the means and SD of the nRMS values were calculated. Repeated measures ANOVA was used to evaluate differences in EMG activity between groups, left and right sides. Within-group comparison was the EMG measurement at rest and maximal voluntary clenching. An alpha level of $P<0.05$ was considered significant.
RESULTS: Analysis of the SCM muscles data, showed a significant difference in EMG activity between groups ($P=0.04$) and between clenching and rest ($P=0.00$). Significant interactions were found for clenching/rest and groups ($P=0.03$). There was no significant difference between sides for SCM muscles. Although the nRMS value of the trapezius muscles was higher in the patient group, no significant differences was identified between control and patient groups or sides during each condition. A significant difference was seen between rest and clenching ($P=0.00$).
CONCLUSIONS: These finding suggest that the maximal voluntary clenching actives the SCM and trapezius muscles. Further research is needed to clarify a functional co-activation of these muscles.

T10.P19
MUSCULAR ASSESSMENT OF THE TRAINING TECHNIQUES OF THE SUPERIOR LIMBS IN THE PULMONARY REHABILITATION PROGRAM: DIAGONAL MOVEMENT VERSUS ROWING

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Center Academical July Nine - UNINOVE - Brazil

AIMS: The Chronic Obstructive Pulmonary Disease (COPD) is characterized by the obstruction of the air flow, is not totally reversible, occurring important limitation in physical capacity and daily life activities of the patients. The superior limbs training in activities using great muscular groups decrease the oxygen consumption and dyspnea to an equal charge, leading the muscular conditioning of the superior limbs a necessary practical in the pulmonary rehabilitation program, however, it is questionable the best way to perform it. To help responding such question, we search for analyzing the pattern of electromyographic activity of the trapezius muscle - superior fibers, great dorsalis, pectoralis major and e biceps brachii, besides muscular fatigue developed during the diagonal movements (DM) and seated rowing (SR).
METHODS: These prospective studies, 10 patients with COPD diagnosed according to the criteria defined by GOLD, were randomized in two training activities for a determined period of two minutes. To the statistical analysis of the data, it was used the crossed correlation test, point by point, during all the cycle of movement to the behavior of the electromyographic activity; to the angular coefficient (AC) parameters, obtained by the linear regression line of the median frequency, it was used the student's T test ($p<0,05$).
RESULTS: The behavior of the electromyographic curve of the rowing exercise and the diagonal test ($p=0,01$), and the AC of the rowing exercise ($-18,25\pm4,59$) when compared to the diagonal exercise ($-13,78\pm4,45$) of the superior limb showed statistically significant ($p=0,02$).
CONCLUSIONS: According to the showed results, we suggest that the seated rowing exercise can be another way of training for the superior limbs when compared its level of fatigability to the diagonal movement.

T10.P20
EMG TOPOGRAPHY DURING ISOMETRIC, FATIGUING CONTRACTION OF THE UPPER TRAPEZIUS

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AIMS: Modifications in the spatial distribution of EMG activity during sustained contraction indicate variations in the sharing of the load among regions of the muscle and thus may play a role in the maintenance of the force output. The aim of the study was to verify the hypothesis that changes in the spatial distribution of muscle activity have the functional role of reducing fatigue development.
METHODS: Eleven healthy, right-handed male subjects (age, mean±SD, 28.2±5.7 yr) participated to the study. Surface EMG signals were recorded with a 13 x 5 electrode (2-mm diameter, 8-mm interelectrode distance) grid from the upper trapezius muscle of the dominant side, between the seventh cervical vertebra (C7) and the main innervation zone (Figure). Subjects were asked to maintain a 90° shoulder abduction position until exhaustion. To assess spatial inhomogeneity in muscle activation and its changes over time, the entropy and center of gravity of

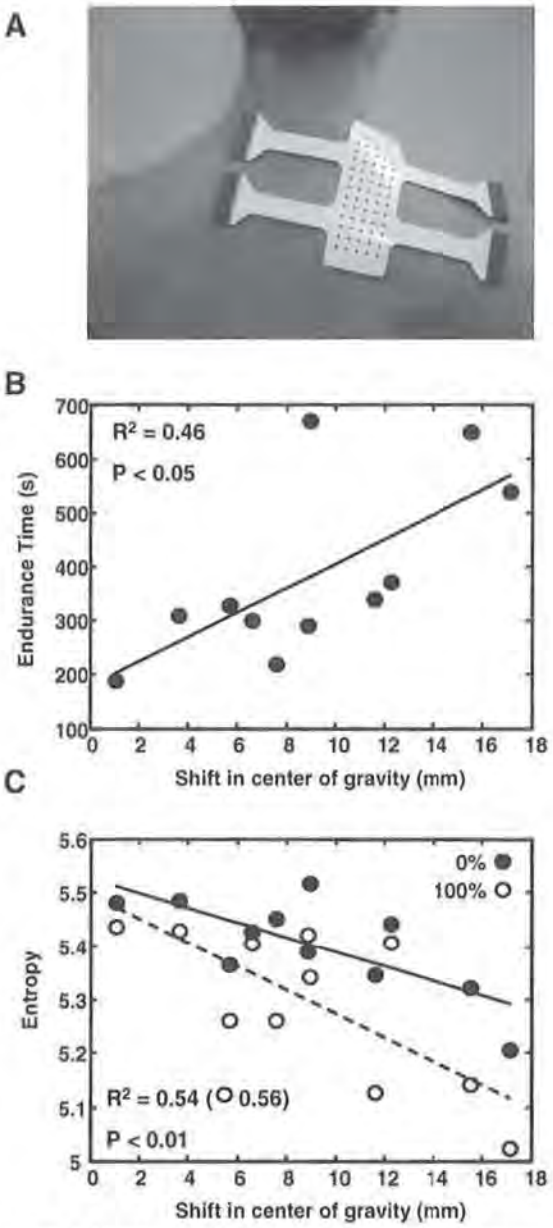

Figure. A: Location of the electrode grid on the upper trapezius muscle. Scatter plot of the shift of the center of gravity of the root mean square map and endurance time (B) and entropy (C).

the EMG root mean square map were computed at 0%, 25%, 50%, 75% and 100% of the exercise duration.

RESULTS: At the endurance time, entropy decreased (mean± SD, percent change 2.0±1.6 %; P<0.0001) and center of gravity moved in the cranial direction (shift 11.2±6.1 mm; P<0.0001) with respect to the beginning of the contraction. The shift in center of gravity was positively correlated with endurance time (R^2=0.46, P<0.05; Figure). The percent variation in average (over the grid) root mean square was positively correlated with the shift in the center of gravity (R^2=0.51, P<0.05). Moreover, the shift in the center of gravity was negatively correlated to both initial and final (at the endurance) entropy (R^2=0.54 and R^2= 0.56, respectively; P<0.01 in both cases; Figure).

CONCLUSIONS: The results indicate correlation between the change in the spatial distribution of muscle activity over time and endurance time. Subjects with more heterogeneous activity (smaller entropy) and larger shift in the upper trapezius activity toward the cranial direction could sustain the static contraction longer than subjects with more uniform activity distribution and smaller changes in the EMG map over time. Thus, heterogeneity in muscle activity and spatial adaptation over time have the functional role of prolonging sustenance of a static task.

Grants: Marie-Curie Fellowship of the European Community program "Marie Curie Training Sites" (HPMT-CT-2000-00092) and the Danish Technical Research Council (project "Centre for Neuroengineering (CEN)", contract n° 26-04-0100).

Neurophysiology

THE RECRUITMENT ORDER OF ELECTRICALLY ACTIVATED MOTOR NEURONS INVESTIGATED WITH A NOVEL COLLISION TECHNIQUE

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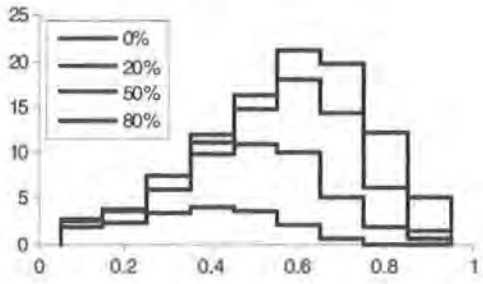
AIMS: Electrical stimulation is a promising tool for rehabilitation of paralyzed patients. For this purpose, it is essential to know the recruitment order of motor neurons that are activated by electrical stimulation, which is currently a controversial issue [1;2]. Therefore, this study aims to investigate motor neuron recruitment order with surface electrical stimulation using a novel collision technique.
METHODS: Teen healthy male subjects (age range 21 - 30 yr) participated in the study. The ulnar nerve was stimulated with surface electrodes at the elbow and wrist. The compound muscle action potential was recorded from the abductor digiti minimi muscle with surface electrodes in the belly-tendon configuration. A modified version of Hopf's collision technique (cited in [3]) was developed to determine the conduction velocity distribution (CVD) of electrically activated nerve fibers. In Hopf's technique, the CVD of a nerve is estimated with a distal and a proximal stimulus which is delayed with respect to the first. A 0.2-ms proximal test stimulus, 1-ms prior to the first distal stimulus, was included at an intensity corresponding to 20%, 50%, and 80% of the maximal response. The nerve fibers activated by the test stimulus generate action potentials which always collide with those generated by the proximal stimulus. Consequently, the method allows the estimation of the CVD of the nerve fibers not activated by the test stimulus. Harayama's technique was used to correct for the velocity recovery effect in the muscle and the refractory period in the nerve fibers [4]. All results are given as mean and SE.
RESULTS: The range of conduction velocity (5% - 95% percentile) of the whole nerve (0% test stimulus) was 50.8±0.80 m/s ÷ 61.6±0.78 m/s. The median of the CVD for 0%, 20%, 50%, and 80% test stimuli was 56.5±0.80 m/s, 55.9±0.85 m/s, 54.7±0.88 m/s, and 53.1±0.87 m/s, respectively. All median values were different between each other (one-way repeated measures ANOVA, $F = 124.2$, $P << 0.0001$; post-hoc Student-Newman-Keuls test, $P < 0.001$; see Figure).



Averaged CVD over all subjects for the four test stimuli Conduction velocity (CV) is normalized so that the range is 0-1 for all subjects (x-axis: 0: minimum CV, 1: maximum CV). The distributions correspond to the fibers not activated by the test stimulus, thus 0% test stimulus correspond to the whole nerve CVD

CONCLUSION: The decrease in median of the CVD of the not activated nerve fibers with increasing stimulus intensity, supports the theory that nerve fibers are recruited from large to small with electrical stimulation using surface electrodes.

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IDENTIFICATION OF MAXIMAL M-WAVE DURING TRANSCUTANEOUS STIMULATION IN HUMAN TIBIALIS ANTERIOR

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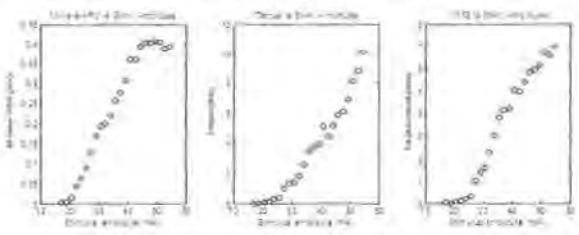
AIMS: This work was aimed to define a reliable experimental procedure to identify the transcutaneous stimulation current generating the largest surface myo-electrical response i.e. the maximal M-wave (M-wave$_{MAX}$). To reach this goal the analysis of the evoked M-wave, torque and TA surface displacement (mechanomyogram, MMG) has been performed.
METHODS: The leg of seven young males was placed in an ergometer for ankle dorsiflexors isometric contraction. The ankle was fixed in the neutral position. The foot was strapped to a wooden plate connected to a load cell for torque measurement. A 3x3 cm adhesive cathode electrode was placed on the main motor point (MP) of tibialis anterior (TA) and a large anode plate was located on the gastrocnemious. The EMG was detected by an eight-electrodes adhesive array (interelectrodes distance=0.5 cm) positioned parallel to the muscle fibers between the MP and the distal tendon. A laser distance sensor detected the TA MMG between the MP and the EMG electrodes array. A 20 Hz 3 s long stimulation train, with 200 ms symmetric biphasic square current wave, was used to stimulate the muscle. The stimuli amplitude (Amp) was initially set at 17 mA$_{PEAK}$. After this first stimulation, Amp was increased in 1.7 mA$_{PEAK}$ steps and the subsequent trains were administered with 1 minute interval. The procedure was interrupted when Amp reached the pain threshold. In order to avoid influence of transient phenomena, for each stimulation level the mean M-wave have been computed over the 40 responses of the last two seconds of stimulation. In the same time window the average torque and MMG were calculated. The largest of the seven single differential signals, recorded with the array, has been selected. From the mean M-wave of the selected channel the average rectified value (ARV) has been estimated on a 25 ms time window were the stimulation artifact was not present.
RESULTS: For all subjects it was possible to identify a stimulation amplitude (range: 36,50 mA$_{PEAK}$) eliciting the M-wave$_{MAX}$. From figure 1 is clear that beyond this amplitude (Amp$_{MAX}$) the evoked M-wave plateaued; this was not true for torque and MMG.



M-wave ARV, Torque, and MMG vs stimulation amplitude in a representative subject

CONCLUSION: The discrepancy between the TA electrical and mechanical responses suggests that beyond AmpMAX it could be possible to recruit some deep TA motor units or TA agonists muscles contributing to the output torque and overall muscle displacement

but not to the M-wave. Future studies monitoring the EMG activity of TA agonists will help to get some data on the reliability of this hypothesis and to define the precision of the technique we adopted in this work.

ARCHITECTURE OF A SERIES-FIBERED HUMAN MUSCLE: EMG STUDY OF BRACHIORADIALIS

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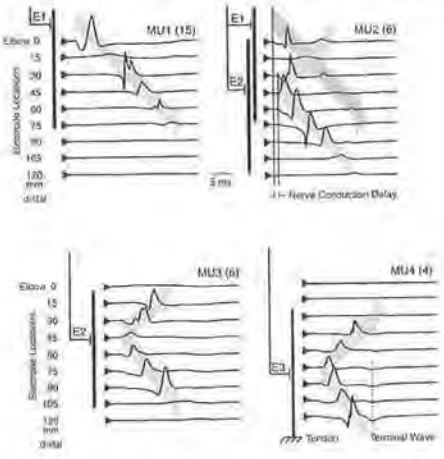
AIMS: Muscle architecture is a main determinant of muscle function. Traditionally, human muscles are considered as consisting of fibers that extend from tendon to tendon and receive innervation at a single endplate. Thus every muscle fiber belongs to a single motor unit (MU) and the force generated during activation is directly transmitted to the tendons. Although the existence of animal muscles formed by serial arrangement of overlapping bands of short fibers is well documented, there is a limited evidence of series-fibered architecture in humans. Brachioradialis (BR) displays similarities with animal series-fibered muscles: a parallel-fibered muscle with the longest fascicles in the arm, several endplate zones, and intrafascicularly terminating fibers. We employed EMG methods to study the architecture of multiple MUs in BR.
METHODS: Intramuscular EMG signals were collected from the right BR of twelve normal volunteers during moderate isometric contractions. Signals were recorded from up to 12 locations along the muscle's proximodistal axis. EMG decomposition was used to obtain motor-unit action potentials (MUAPs) at different electrode sites. By analyzing the MUAPs' morphological features and propagation pattern the architecture of 30 MUs per muscle (on average) was reconstructed.
RESULTS: In ten muscles we found three to five distinct endplate zones separated by at least 15mm. Some MUs were innervated in only one zone. However, many MUs in all ten muscles were innervated in two zones and a few MUs in several muscles were innervated in three zones. Consistent with our previous study (Lateva et al., 2002) muscle fibers innervated by two motoneurons at different zones were found in all ten muscles. The Figure illustrates results from one subject in which three endplate zones (E1-3) were found based on the analysis of 31 MUs. Each subplot shows a representative MU for the identified four architectural classes: 15 MUs were innervated in E1, 6 MUs in E2, 4 MUs in E3, while 6 MUs were innervated both in E1 and E2. The nerve conduction velocity between the two zones for MU2 was 50m/s, consistent with a myelinated nerve branch. MU1 reduced progressively in size distally and MU4 proximally suggesting intrafascicular termination. In the remaining two muscles we found only one zone. Notably, these muscles had the shortest lengths.



CONCLUSIONS: 1) BR architecture varies widely between subjects. 2) BR has multiple distinct endplate zones and intrafascicularly terminating fibers, consistent with a series-fibered architecture. 3) Some motoneuron axons branch to innervate multiple zones showing that a MU can consist of muscle fibers in different bands. 4) Some muscle fibers are innervated by two different motoneurons and thus belong to different MUs.
5) A physiological constraint on muscle fiber length may explain why subjects with only one endplate zone have shorter muscles. 6) The findings add to our knowledge of MU architectural complexity in BR and possibly other long, parallel-fibered muscles. 7) Better knowledge of MU architecture is essential for understanding the generation and transmission of force in series-fibered muscles.

THE EFFECT OF MUSCLE CO-CONTRACTION ON STRETCH REFLEX RESPONSES IN MUSCLES CROSSING THE ELBOW

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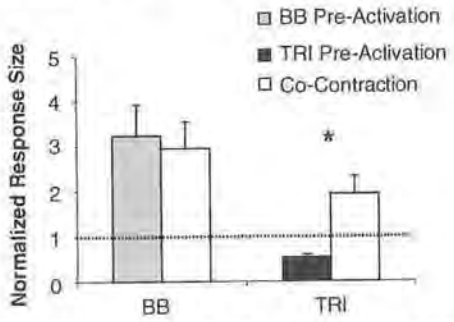
AIMS: It has been shown that muscle co-contraction influences the regulation of the short latency reflex response to muscle stretch. There has been less extensive investigation the reflex response to muscle shortening. It is the net response of all muscles acting about a joint that determines the mechanical consequences of stretch-sensitive reflexes. Therefore, the aim of this study was to examine the effect of elbow joint perturbations on the short latency reflex response to lengthening and shortening when the antagonistic muscles crossing the elbow are co-contracted.
METHODS: Rapid ramp-and-hold displacements were applied to the elbow joint of nine subjects during controlled activation of the biceps (BB), brachioradialis (BR), and/or the lateral head of the triceps (TRI) muscles. Perturbations were delivered in both the elbow flexion and extension directions. During each set of perturbations, an elbow flexor, elbow extensor, or both flexor and extensor muscles were pre-activated at graded levels (0-10%) of maximum voluntary contraction. Reflex responses were quantified in terms of the average rectified electromyogram (EMG) in a 25 ms window beginning at the onset of the earliest response following the perturbation. Results are the average of 20 perturbations for each experimental condition.
RESULTS: In the TRI, elbow extension perturbations delivered while the TRI was pre-activated alone gave rise to a stereotypical inhibition of the on-going TRI muscle activity. When TRI and BB (or BR) were co-activated, elbow extension perturbations elicited an excitatory response in the TRI. This even occurred at very low levels of elbow flexor pre-activation. Responses in the (lengthened) elbow flexor muscles were not different between isolated flexor pre-activation and co-activation with TRI. Shortening reflex responses in the elbow flexor muscles also were modulated by co-contraction, but not to the same extent as the elbow extensor muscle.
CONCLUSIONS: Reflex responses in the elbow muscles elicited by rapid joint perturbations can be modulated by the state of activation of the reciprocal muscles. This modulation appears to be more robust in the elbow extensor muscle compared to the elbow flexors. The modulation of response size provides further evidence that the neural control of short-latency reflexes serves to regulate the joint as a whole, rather than the individual muscles acting about that joint.



Reflex EMG magnitude in the BB and TRI following elbow joint extension perturbations. Response sizes are normalized to level of muscle pre-activation. Note the TRI response is inhibitory during isolated TRI pre-activation and excitatory during co-activation with BB

INTROSPECTIVE KINESTHETIC ILLUSION ACTIVATES MOTOR EXECUTION SYSTEM MORE STRONGLY THAN SIMPLE ACTION OBSERVATION IN HUMAN

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AIMS: The purpose in the present study was to reveal the physiological effect of the illusory feeling on the motor output system during misunderstanding someone else's action as one's own.

METHODS: Twenty healthy male subjects (age 21-31 years) participated in this experiment. All subjects were self-declared right-hand dominant. During the experiment, the subject sat on a comfortable chair with his left hand on a custom-built experimental table. Surface electromyography (EMG) signals were recorded from the first dorsal interrosseous (FDI) muscle and abductor digiti minimi (ADM) muscle. Four kinds of testing conditions were arranged in this experiment to record motor evoked potentials (MEP) after transcranial magnetic stimulation (TMS). TMS was applied during resting condition before the other three conditions (named "illusion," "non-illusion," and "sham"). In illusion, a computer screen showing the abduction of someone else's index finger was placed on the subject's distal forearm. The position of the screen was adjusted so that the subject would see the action on the screen as if watching his own index finger moving. In non-illusion, the subject was instructed to watch a computer screen showing the abduction of someone else's index finger corresponding with the moving image of the illusion condition. The difference between illusion and non-illusion was that, in the latter condition, the subject could recognize that his own finger was not moving, since his own static hand was in his field of view. In sham, the subject was shown white 3D text moving on the computer screen. TMS was delivered through a round coil placed in the manner of A facing up (RdA) or B facing up (RdB) around Cz. A figure-8 coil (F8) was also used at the right optimal scalp position. Furthermore, regional brain activation is visualized by means of multi channel near-infrared spectroscopy (NIRS).

RESULTS: MEP recorded from the FDI under illusion condition was largest compaired to that induced under other conditions (RdA, RdB). On the other hand, there was no significant difference of MEP amplitude among the conditions in the ADM. Illusion condition activated arround primary motor cortex was confirmed by NIRS topography. In post-experiment interviews, the subjects commented as follows: In the illusion condition, they felt completely as if their own finger was actually moving. In the non-illusion condition, however, they clearly recognized that their own finger was relaxed while someone else's finger was abducting on the screen.

CONCLUSIONS: We found the existence of a neuronal circuit that works as a kinesthetic-illusion and motor-execution linkage (KIMELI), although it is uncertain whether this circuit laps over with the mirror neuron system. Motor reproduction from motor experience (memory) may induce this facilitation, as reported as in the case of motor imagery. The present results suggest that illusory kinesthetic sensation of movement was not just a feeling but had physiological meaning strongly connected to the motor execution system in the human brain. The illusion accomplishes a facilitative effect on the motor execution system, possibly indicating that virtual action experience affects the motor execution system accompanying motor learning. The KIMELI has the potential for applications in therapeutic intervention.

THE BRAIN SYMMETRY INDEX AS A FEATURE FOR A BRAIN COMPUTER INTERFACE

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AIMS: To improve the qualtiy of life for people with severe damage to the motor pathways (e.g. spinal cord injury) brain computer interfaces are developed [1]. Here, the Brain Symmetry Index [2] is evaluated as a feature for controlling an object on the computer screen.

METHODS: The subject is asked to move a square object in the vertical direction with the goal to hit a target. The object moves in the horizontal direction of the screen from the left to the right. the target is situated in the upper of lower half of the screen.

To control the cursor the EEG is recorded, over C_3 and C_4 in reference to F_z, with a sample frequency of 256 Hz from which the 200-point Fast Fourier is calculated. The 2nd and 3rd coefficient are used to determine the BSI-value.

The hardware setup consists of an 18 channel analog EEG-system, connected to a computer via a National Instruments A/D-card. the Mathworks Matlab R14 environment is used to acquire and analyse the eeg-recordings.

RESULTS: first results on a group of three healthy subjects show a hit rate between 70-80% after one session training (nine runs). It is expected that further training and optimizing of the method will lead to an increase in the hit rate.

CONCLUSIONS: The first results are promising and suggest that the BSI is a useful feature for BCIs. Currently, additional optimization and training of subjects are performed to increase the performance.

The Bci-System In Action

[1] Wolpaw, J. R. Et Al. (2002). Brain-Computer Interfaces For Communication And Control. *Clinical Neurophysiology*, 113(113), 767-791.

[2] Van Putten, M. J. A. M. Et Al. (2004). A Brain Symmetry Index For Online Eeg Monitoring In Carotid Endarterectomy. *Clinical Neurophysiology*, 115, 1189-1194.

A NOVEL APPROACH FOR THE ESTIMATION OF MOTOR NERVE CONDUCTION BLOCK

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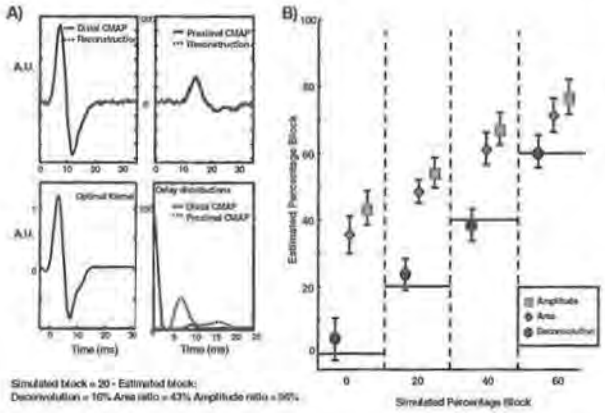
AIMS: The determination of conduction block (i.e., the failure of an action potential to propagate through an intact axon) can rely on the comparison between the compound muscle motor action potential (CMAP) following stimulation at sites proximal and distal to the region in which a block is suspected. A reduction of the amplitude or of the area of the CMAP following proximal

versus distal stimulation is an accepted indication of conduction block in clinical practice. Nerve and muscle conduction velocity spread determines a temporal dispersion of the motor unit action potentials (MUAP) constituting a CMAP; as a consequence, phase cancellation can occur in the MUAPs which add up in the detected CMAP. CMAP amplitude and area are strongly affected by temporal dispersion of the MUAPs. The aims of this study is the development of a novel method for the estimation of motor nerve conduction block which is insensitive to temporal dispersion.

METHODS: The new method for the estimation of conduction block is based on the deconvolution of the CMAP. As shown in Figure A for a representative simulated example, it provides an approximate reconstruction of the distally and proximally elicited CMAP, expressed as convolutions of estimated delay distributions with a kernel (chosen in order to optimally reconstruct the CMAPs). The integral of the delay distribution is considered as an estimate of the number of active motor units, and is used to estimate conduction block.



Comparison of the new method with area and amplitude based methods, in the case of high temporal dispersion. A) Example of reconstruction of distal and proximal CMAP, estimated kernel and delay distributions. B) Estimated conduction block (average and standard deviation over 10 realisations)

RESULTS: Simulated signals (from a plane layer generation model of surface EMG) were used to compare the new method to those based on amplitude and area. Deconvolution method gives more precise estimates of the simulated conduction blocks with respect to area and amplitude methods (see Figure B). The method has low sensitivity to temporal dispersion (in Figure B, temporal dispersion was simulated by using a distribution of nerve conduction velocities lower than 45 m/s).

CONCLUSIONS: A new method for nerve conduction block estimation is proposed. The method is promising for the accurate estimation of the block and shows low sensitivity to temporal dispersion.

CHANGE OF H-WAVE AND MEP DURING PEDALLING BY ONE LEG

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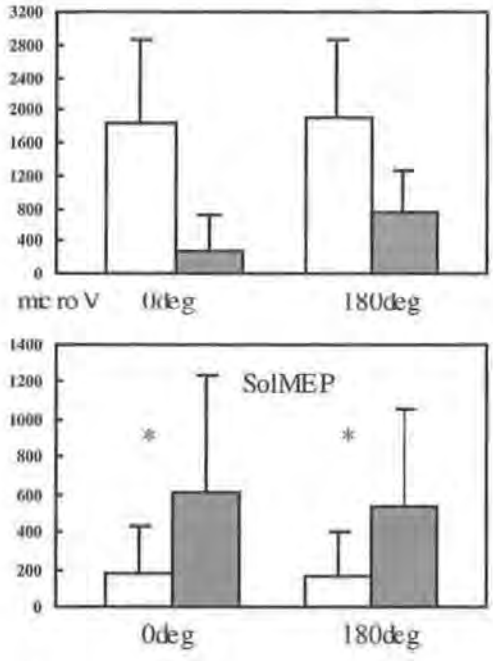
AIMS: We previously reported post-stroke patients with severe hemiplegia could drive a cycling chair and the muscles in the paretic lower limb showed significant activities during pedaling. It suggests a possibility that driving a cycling chair facilitates the neuronal system controlling the paretic lower limb. However it is unknown whether pedaling movement of the healthy leg brings some reflexes to the paretic muscles or effort of pedaling by the healthy leg activates the motor cortex of the contralateral side. The purpose of this study is to investigate the influence of the pedaling movement performed by one leg to the neuronal systems.

METHODS: Eight healthy adults (20.3±0.9 years) and two hemiplegic stroke patients (A, B) participated in this study. Pedaling was performed with a recumbent type ergometer. At first, during rest, H-wave was recorded from left (paretic) Soleus muscle (SolH) and then motor evoked potential (MEP) induced by trancranial magnetic stimulation (TMS) was recorded from left (paretic) Soleus and Tibialis anterior muscles (SolMEP, TAMEP). After that, during pedaling by right leg (healthy leg) with rotation speed at 40rpm, H-waves and MEPs were recorded as same as resting state. Electrical stimulation to elicit H-wave was given to the popliteal fossa with the intensity of 50% of H max. TMS was applied to Cz on the scalp with the intensity fixed at 120% of motor threshold. H-waves and MEPs were recorded at 0 and 180 degrees of crank angle both during rest and pedaling and 8~10 waves in each were averaged with EPlizer (Kissei Comtec. Inc.).

RESULTS: In the healthy subjects, the mean amplitude of SolH during pedaling was significantly decreased in both 0 and 180 degrees of crank angle compared to rest. Meanwhile, the mean amplitude of SolMEP and TAMEP in both 0 and 180 degrees were significantly increased (Figure). While the amplitude of SolH did not change in both patients, TAMEP in the patient B appeared during pedaling in all trials though it did not appear during rest. SolMEP in both patients and TAMEP in the patient A could not be recorded even during pedaling.

CONCLUSIONS: The results of the healthy subjects suggest that during pedaling by one leg the activity of spinal motor neuron dominating the soleus muscle in the contralateral side is inhibited. However, in the hemiplegic stroke patients, the amplitude of SolH showed no change during voluntary pedaling. As the spinal cord of the patients was intact, these suggest the decrease of the activity of spinal motor neuron dominating the contralateral soleus muscle is based on the inhibiting mechanism from the brain.

The increase of the amplitude of SolMEP and TAMEP in the healthy subjects implies the effort of pedaling movement by one leg induces increment of the cortical excitability in the bilateral hemisphere and the excitation will transfer to the spinal motor neuron via corticospinal tract. The appearance of TAMEP in the patient B during voluntary pedaling by healthy leg suggests that pedaling movement can facilitate motor function of the paretic lower extremity associated with cortical excitation even in the hemiplegic stroke patients. However, it seems contradictory that inhibition of the spinal motor neuron caused by descending impulses from the brain and facilitation of the spinal motor neuron associated with cortical excitation are both via corticospinal tract. Therefore it is valid to postulate that the inhibitory impulses from the brain to the spinal motor neuron generated during voluntary pedaling descend via the pathway except corticospinal tract.



EFFECTS OF HYPOXIA ON NEUROMUSCULAR ACTIVATION

Szubski C, Burtscher M, Löscher W
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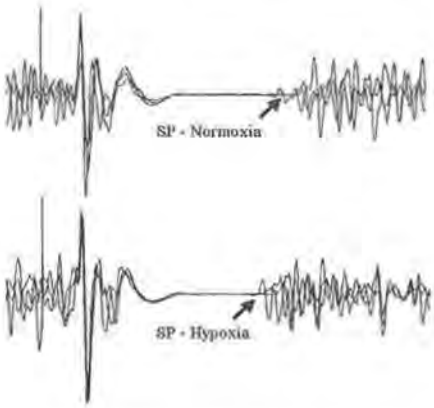
AIMS: Previous studies on neuromuscular activity at high altitude were focused on peripheral mechanisms. In this protocol, adaptations of contractile properties, neuromuscular transmission, spinal and motor cortical excitability in response to short-term normobaric hypoxia were assessed at rest and during brief muscle contractions.
METHODS: Fourteen healthy male volunteers (23-45 years) participated in this study. Electrical supramaximal stimulations of the right ulnar nerve were performed and transcranial magnetic stimulations (TMS) were delivered to the left First Dorsal Interossoeus (FDI) motor cortex area. M-wave, voluntary activation, F-waves, resting motor threshold (rMT), recruitment curve (100-140% of rMT), short interval intracortical inhibition (SICI) and facilitation (SICF) were measured. Moreover, motor-evoked potential (MEP) and cortical silent period (SP) were determined during 3 brief maximum right index finger abductions (MVC). Hypoxic condition was induced by breathing a fraction of inspired oxygen (FIO_2) of 12% via face mask. The normoxic (NR) and hypoxic (HX) sessions were randomised and performed at least 3 days apart. Paired Student's t-tests and two-way repeated measures ANOVA were performed. Values given below were mean ± SD. The level for statistical significance was set to $P<0.05$.
RESULTS: M-wave, voluntary activation and F-waves did not differ between NR and HX. The rMT was significantly lower in HX compared to the threshold in NR (-1.71% of stimulator's output; $P<0.01$) while MEP recruitment curves did not differ between NR and HX. Also, SICI and SICF were unaffected by HX, and MVC and MEP were similar in both conditions. In contrast, the SP in hypoxic condition (158.21±33.96ms) was significantly shortened compared to NX (169.42±39.69ms) ($P<0.05$).
CONCLUSIONS: Lower rMT and shortened SP suggest hypoxia-induced increase in neuronal membrane excitability of the cortical motoneurons and enhancement in the rate of Glutamate release within cortical synapses, respectively. During MVC these changes can probably be overcome by voluntary drive.



Three overlaid SPs (characteristical signals)

CORTICAL RECIPROCAL INHIBITION IS REDUCED IN OLD HUMANS

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AIMS: Coordination between agonist and antagonist muscles is a principal form of movement control yet the mechanisms of the age-related increase in antagonist muscle activity is unknown (Hortobágyi and DeVita, *Exerc Sport Sci Rev* 31, 2006). There is some evidence indicating a reduction in spinal reciprocal inhibition with advancing age (Kido et al. *Can J Physiol Pharmacol* 82:238, 2004). Because spinal and cortical reciprocal inhibition may be the primary mediators of the age-related changes in antagonist muscle activation we determined if age alters the inhibitory actions from wrist flexor afferents on the corticospinal outputs to the antagonist wrist extensors.
METHODS: In young (age 27, n = 6) and old (age 73, n = 6) adults a mild conditioning electrical stimulus was delivered to the median nerve at the elbow (agonist flexor carpi radialis, FCR). The test stimulus, delivered by transcranial magnetic stimulation (TMS) at 1-ms increments between 11 to 24 ms after the electrical conditioning stimulus, evoked motor potentials (MEP) in the antagonist extensor carpi radialis (ECR) and also in the agonist FCR muscle. In control experiments we examined the effects of electrical conditioning stimulus on test MEPs in the first dorsal interosseus muscle as well as the effects of high intensity electrical conditioning stimulus on test MEPs in the ECR.
RESULTS: The absolute TMS intensity, expressed as the percent of stimulator output, used to produce 1-mV control MEPs in the ECR was similar in young (58.5±SD12.8%) and old adults (60.3 ±20.3%, $p=0.855$). The size of the control MEP in the ECR was also similar in young (0.98 ±0.10 mV) and old subjects (0.90 ±0.14 mV, $p=0.686$). The age by conditioning interval interaction ($p=0.001$) showed that the MEPs in the ECR were significantly depressed at 14, 15, 16, 17, 18, and 19 ms (range 55.5 to 65.9% of control, all $p < 0.05$) compared with control value of 100% and with old adults who showed no depression. The MEPs remained at control level in the FCR and were also unaffected in the first dorsal interosseus.

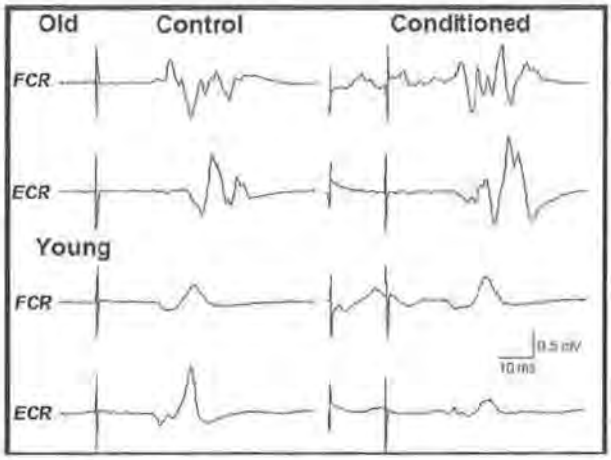

Figure shows trials of cortical reciprocal inhibition in a person age 76 and 26. TMS produced MEPs in the right FCR and ECR. Control trials without a conditioning stimulus and trials conditioned with a weak peripheral electrical stimulation of the median nerve at the elbow at a conditioning interval of 17 ms. Note the absence of cortical reciprocal inhibition in old (right column, second tracing from the top) and strong inhibition in the young adult. Each tracing is the average of 20 Control and 12 Conditioned trials.
CONCLUSIONS: These data confirm the existence of cortical reciprocal inhibition reported previously in young humans and show that age reduces this inhibition similarly to the previously reported reduction of spinal reciprocal inhibition reported in old adults. Activation of agonist and antagonist muscle pairs is most likely organized around a dual system of centrally and peripherally mediated reciprocal inhibition which is altered by age. The data also indicate the need to use age-matched control subjects when comparing individuals with abnormalities resulting from disorders that occur at an advanced age.

T11.P01
RELIABILITY OF DIFFERENT METHODS OF DETERMINING THE LATENCY OF A MOTOR EVOKED POTENTIAL AT THE INFRASPINATOUS

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AIMS: The latency of a motor evoked potential (MEP) can been used to study the central and peripheral neural structures between the motor cortex and peripheral muscles. Several methods of measuring latency have been used in the literature, including the first zero crossing of the MEP, and 1, 2 or 3 standard deviations (SD) from the baseline. The first purpose of this study was to determine the most reliable method of determining MEP latency to the infraspinatous. The second purpose was to determine if normal side-to-side differences in MEP latency exist.
METHODS: 14 subjects (10 female, 4 male, all right-hand dominant, age 32.7±8.1), BMI 22.8 (±3.8) gave informed consent. Surface electrodes were placed bilaterally at the lateral scapular spine (inactive) and over the motor point (active) of the infraspinatous. A carbon-rubber reference electrode was placed across the lower cervical spine. Using transcranial magnetic stimulation the MEP threshold, where discernable MEPs are produced 50% of the time, was determined while subjects performed a continuous facilitating contraction of 20% of their maximum effort. Twenty percent of the threshold stimulus intensity was added and 10 MEPs were recorded from the infraspinatous with a sampling rate of 2kHz. The latency from the onset of the stimulus artifact to the first zero-crossing of the MEP was determined with visual inspection. Latencies were also determined by calculating the SD of 25ms of baseline activity prior to each stimulus, and visually determining where the MEP tracing first crossed a line 1, 2 and 3 SDs from baseline. The coefficient of variation of the MEP latency was calculated using each method across the ten trials for each subject. A one-way repeated-measures ANOVA was performed to test which method was most reliable. The most reliable method was used to determine if there were side-to-side differences using a one-way repeated-measures ANOVA.
RESULTS: The mean (SD) latency values (in ms) for the zero-crossing, 1, 2 and 3 SD methods were 17.6 (1.4), 9.6 (2.3), 11.2 (2.5) and 12.7 (2.8) respectively. Figure 1 shows that the zero-crossing method of determining latency had a smaller coefficient of variation (2.92%) than the one (24.43%), two (19.96%) or three (17.10%) SD methods, and was significantly more reliable than the other methods ($p<0.005$). There was a significant interaction between subject and side ($p<0.005$) but no side main effect ($p=0.204$). The mean side-to-side difference was 0.84±0.64 ms.
CONCLUSIONS: There was substantial variability in latency measurements among healthy individuals as noted by the large SDs. The zero-crossing method was far more reliable than the others in determining the latency of a MEP to the infraspinatous.

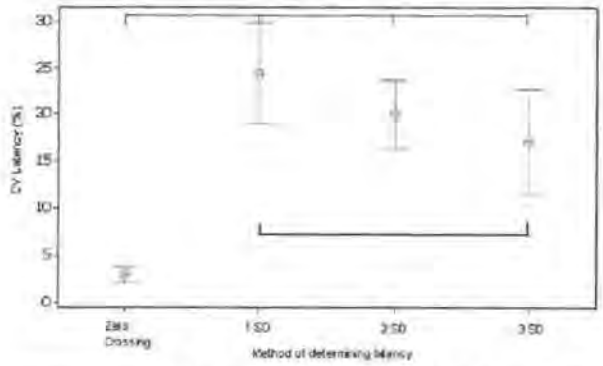

Figure 1: Coefficient of variation for each method of determining latency, (mean±2SD). Bars denote a significant difference at alpha=0.05

The mean side-to-side difference and the lack of a significant difference between left and right sides suggests that a side-to-side difference greater than 2.1ms can be used to detect conduction abnormalities when testing the MEP latency from the motor cortex to the infraspinatous.

T11.P02
EFFECTS OF GENDER AND AGE ON AXONAL EXCITABILITY

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AIMS: To evaluate the possible effects of gender and age on axonal excitability.
METHODS: The strength duration time constant of 114 healthy volunteers were measured following stimulation of right median nerve at the wrist. The values of females and males and in different age ranges were evaluated.
RESULTS: The axonal time constant was 438.6±114 μs in females and 393.5±101 μs in males ($P=0.031$). Our findings demonstrate a difference in excitability, confined to young patients.
CONCLUSIONS: As axonal excitability depends on the biophysical properties of the axonal membrane and can provide some information about Na^+ or K^+ channel function, these data raise the possibility of a difference in Na^+ channel function in males and females, and a difference in the conductance with aging. The age- and gender-related differences showed in this study suggest a possible biochemical or hormonal influence on axonal excitability.

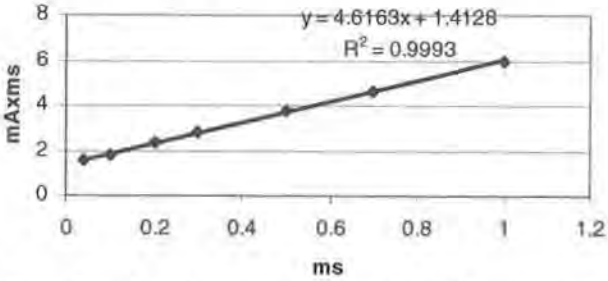

Figure: The relation between stimulus duration and the value got by multiplying stimulus strength with stimulus duration (charge). The calculation of time constant.

T11.P03
THE EFFECT OF AGE ON CHEWING

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AIMS: Old-age is the last stage of human evolution and, unfortunately, the aging rhythm of the oral cavity and masticatory system seems to be rather accelerated. Hence, as a consequence, there is a reduction in the amount of food ingested, establishing the unbalance of nutritional phenomena. To assure a better quality of life for the elderly, it is necessary to understand their masticatory system.
METHODS: An electromyographic analysis was made of the masticatory system in ten individuals in the age range of sixty years-old (group 1) and in ten individuals in the age range of twenty-five years-old (group 2). This analysis was performed using the Myosistem Br-1 electromyograph, during positioning and functional conditions, such as chewing, and the muscles assessed were the temporalis and masseter. Data were normalized by maximum voluntary contraction, and the results were analyzed statistically using T test during the comparison between the groups.

RESULTS: There was statistical significance ($p \leq 0.05$) in the analysis of various activities, in which the elderly showed greater electromyographic activity during different mandibular positions, such as left laterality, and a smaller electromyographic activity during the masticatory activities, such as chewing peanuts.
CONCLUSIONS: It is concluded that the elderly show hyperactivity of masticatory musculature during posture maintenance and a slight hypoactivity of this musculature during chewing when compared to young individuals.

T11.P04
PROPRIOCEPTIVE FEEDBACK CONTRIBUTES TO CORTICAL MAGNETIC FIELDS RELATED TO FINGER EXTENSION

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2)National Nishi-Niigata Central Hospital, Japan

AIMS: The aim of this study was to confirm the contribution of sensory feedback from periphery to generation of the movement evoked cortical magnetic fields.
METHODS: Six healthy volunteers (six males, mean age 23.8 years) participated in this study. Written consent was obtained from each participant before the experiments. Movement-related cerebral fields (MRCFs) were recorded during self-paced voluntary right index extension under three conditions: (Task1) extension ranging of 40 degrees, (Task2) resistant extension ranging of 40 degrees, (Task3) extension ranging of 20 degrees. Neuromagnetic data were recorded using a 204-channel whole-head MEG system (Neuromag, Elekta) in a magnetically shielded room. A total of about 60 epochs were averaged separately for each condition for an interval of -2000ms to 1000 ms with respect to movement onset. Additionally, the EMG signals were detected from the right extensor indicis muscle. To analyze MRCFs, the bandpass filter was set from 0.5 Hz to 20 Hz, and the first 500 ms of those epochs were used to determine the baseline. We identified motor field (MF) and movement evoked field I (MEF1), the major components just before and after movement.
RESULTS: The normalized rectified EMG for Task1 was significant larger than Task 3 and smaller than Task 2. In a similar manner, there were significant differences in MF amplitude among three conditions (36.6±20.0 fT, Task1; 56.0±24.9 fT, Task2; 22.3±11.9 fT, Task3). There were no significant differences in MEF1 amplitude between the Task1 (82.0±21.2 fT) and Task2 (88.4±31.9 fT). The MEF1 amplitude of Task3 (69.7±20.5 fT) was smaller than Task1 and Task2. The latencies of the index movement from EMG onset (electromechanical delay) were 46.0±10.8 ms for Task1, 76.4±15.7 ms for Task2 and 54.7±16.8 ms for Task3. This latency of Task2 was significant longer than other two tasks. However, there were no significant differences of the MEF1 latencies from EMG onset among three tasks. These latencies were 90.2±13.8 ms for Task1, 88.1±8.1 ms for Task2 and 82.8±13.8 ms for Task3.

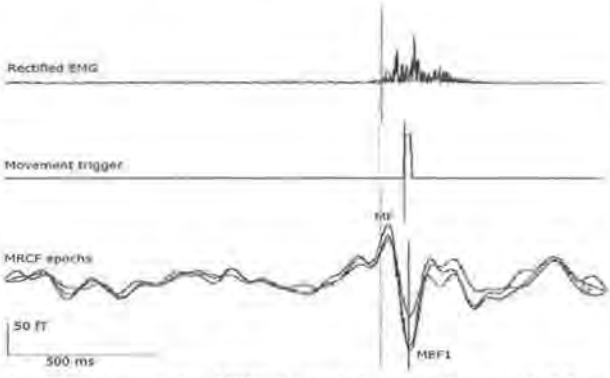

Fig. 1 A representative MRCF during index extension recorded from three lateral position over the left scalp in relation to the EMG and movement Trigger.

CONCLUSIONS: MF amplitude increased with EMG amplitude. This result supports the assumption that MF is generated by activation of primary motor area. The MEF1 amplitude of Task1 was the same as Task 2. These amplitudes were larger than Task3. This result shows that MEF1 was influenced by change of muscle length and not by muscle contraction level. The electromechanical delay of the Task 2 became late compared to Task1 and Tak3. The MEF1 latency from movement onset of Task2 became shorter than other two tasks. However, there were not significant differences of the MEF1 latencies from EMG onset among three kinds of tasks. For this phenomenon, MEF1 responses are attributed to peripheral feedback by a change of muscular length following muscle contraction and not by joint movement. These results showed that MEF1 is generated by cortical activation resulting from muscle spindles input.

T11.P05
CORRELATION AMONG THE SITTING BEARING WEIGHT AND SENSORIAL ALTERATION IN THE GLUTEAL REGION IN HEMIPLEGIC/HEMIPARETIC PATIENTS

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INTRODUCTION: Alterations due to stroke cause important limitations in the ADL and should be specifically analyzed. Known is that hemiplegic patients can have several affected systems, with a great possibility of the balance reactions being affected, influencing in a negative way the stability and symmetry in the seated and standing positions.
AIMS: The objective of this study is to verify the influence of the sensorial alteration in the gluteal region in the weight transfer in the seated position in hemiplegic or hemiparetic patients after a stroke.
METHODS: The study was conducted with 12 stroke patients, presenting hemiplegia or hemiparesia. The test of exteroceptive sensibility was carried out in gluteal region of each patient with the esthesiometer and then the weight transfer was evaluated in the seated posture through "Stabilizer" Biofeedback pressure.
RESULTS: The correlation between sensorial alteration and difference of weight transfer in the seated position suggests that the patients that present sensorial alteration in the gluteal region tend to transfer the weight to the non-plegic side, while the patients without sensorial alteration tend to transfer the weight to the plegic side.

Keywords: Musculoskeletal Equilibrium, Hemiplegia, Stroke, Posture, Somatosensory.

T11.P06
COMPARATIVE ASSESMENT OF THE BALANCE IN CEREBELAR DISEASE AND POST STROKE PATIENTS

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Stroke (Cerebrovascular accident - CVA) and cerebellar ataxia (CA) consist in central compromising conditions that frequently cause balance alterations.
AIMS: The purpose of this study was to compare and quantify the balance alterations in patient bearers of CA and CVA sequelae, in different support bases and under influence of diverse situations imposed to the visual and vestibular system.
METHOD: Consisted in using a test of balance strategies, outlining the systems that influence in these strategies and comparing the degrees of difficulties among patients with cerebellar and encephalic dysfunction. There were used the following postures: standing up, with aligned feet and in unipodal

support, having as variables: closed eyes, opened eyes and with the use of a Japanese lantern, being the surface stable or unstable.
RESULTS: The hemiplegic group presented greater difficulty in the accomplishment of the task with the use of the lantern, sensitizing the vestibular system. The cerebellar group presented greater difficulty in the accomplishment of the task with closed eyes when compared to the stroke group.
CONCLUSION: It was concluded that the two classes of studied patients use their own strategies for balance maintenance, thus enabling to present differences in the performance of balance strategies.

Descriptors: balance, stroke, rehabilitation, assessment, cerebellar dysfunctions.

T11.P07
SOMATOSENSORY EVOKED POTENTIALS OF SUBACUTE MYELO-OPTICO-NEUROPATHY IN RELATION TO SPINAL CORD CONDUCTION VELOCITIES

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AIMS: Subacute myelo-optico-neuropathy (SMON) is the disease elicited by intoxication of clinoquinol which affects mainly the dorsal column and peripheral nerves. The core symptom of SMON is the disturbance of sensory functions such as paresthesia of lower extremities. In order to investigate the neural mechanism of sensory disturbance, the spinal cord conduction velocity (SCCV) between lumbar-to cervical level and the conduction velocity of sensory nerve (SNCV) of sural nerve were examined in the patients with SMON.
METHODS: The spinal cord conduction velocity (SCCV) and the sensory nerve conduction velocity (SNCV) of sural nerve were electrophysiologically examined in 34 patients with SMON. The age of these patients were 48-74 years (median: 65 years) with the duration of illness was 37-48 years (median: 39 years). In order to investigate the SCCVs, the spinal somatosensory evoked potentials (SSEPs) were recorded from the surface electrodes at the level of T12 spine and C2 spine by the simultaneous stimulation of bilateral posterior tibial nerves. SCCV from the level of T12 spine to C2 spine was measured from the latency difference between both SSEPs elicited at the each position.
RESULTS: As the results, SCCVs were 50.6-66.7 (58.6±4.7: mean±SD) m/sec in normal age matched controls (18 adult volunteers, 46-63 years, median: 52.7 years). On the other hand, in SMON patients, SCCVs were in the range of 27.8-55.7 (39.4±9.4) m/sec, and these values in SMON patients were significantly lowered compared to those in normal subjects. These SCCVs in SMON patients were more decreased in the patients with severe disability compared to the values in the patients with mild disability, furthermore the degree of decrease in SCCVs was also correlated to the decrease of the Berthel Index in SMON patients. While the SNCVs in sural nerves were 39.5±8.7 m/sec in SMON patients, and 44.2±6.8 m/sec in normal subjects. These values of SNSVs in SMON patients were not significantly decreased compared to the values in normal subjects.
Since the SSEP impulses are transmitted in dorsal columns and dorsolateral fasciculus predominantly by large diameter and fast-conduction fibers, our results may suggest that, in SMON patients, the decrease in SCCVs reflects the disturbance of ascending fibers mediating the dorsal columns and dorsolateral fasciculus, and that the functional disturbance of those fibers play the important role for the core sensory symptoms in SMON such as the decreased deep sensibility and paresthesia.
CONCLUSIONS: In SMON patients with the core symptom of sensory disturbance such as decreased deep sensation and paresthesia, the spinal cord conduction velocities (SCCVs) from T12 spine to C2 spine level were decreased compared to the values in normal subjects.

T11.P08
MECHANICAL AND SEMG MANIFESTATIONS OF FATIGUE IN SUBJECTS WITH ANOREXIA NERVOSA

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AIMS: Anorexia nervosa (AN) is a severe feeding disorder characterized by prolonged restriction of oral nutrient intake with intentional weight loss associated to morphological, biochemical, and physiological changes in many organs. Mechanical and myoelectric manifestations of fatigue during an isometric fatiguing exercise were compared in anorexic and healthy subjects with the following aims: a) to verify if a fatiguing isometric test can be carried out with such patients, where the pathological conditions could represent a pivotal limitation per se; b) to confirm that AN patients show resistance capacities during endurance exercise even in presence of a merked Body Mass Index (BMI) reduction and muscular ipotrophy; and c) to provide patients with a feedback of their muscular function time course in relation to modifications of feeding behaviours, to allow the integration of clinical evaluations, laboratory analyses, assessment of body composition and energetic metabolism, with a quantitative evaluation of muscular function.
METHODS: Mechanical and myoelectric manifestations of fatigue during an isometric contraction at 80% of maximal voluntary contraction (MVC) were compared in a population of eight anorexic female patients (AN: 24.9±6.5 years, mean±SD) with respect to a group of seven healthy female subjects (CO: 30.0±6.6 years, mean±SD). sEMG signals were recorded, using a linear electrode array (eight channels, 10 mm apart), from vastus lateralis muscle of the dominant side. MVC, endurance time, initial value and rate of change of the EMG variables [conduction velocity (CV), mean power frequency (MNF), average rectified value (ARV)] were the parameters studied during the fatiguing contractions.
RESULTS: Body weight was found greater ($p<0.001$) in CO (57.1±8.0 kg) than in AN (40.3±5.4 kg) and BMI values were found greater ($p<0.001$) in CO (20.0±2.0 kg/m^2) than in AN (15.5±1.7 kg/m^2).
Absolute and relative (normalized with respect to the body weight) knee torque values and endurance times were found not statistically different between the two groups. Similarly, EMG amplitude initial values and rate of changes and MNF initial values were found not different between the two groups. CV initial values and CV rate of changes were found greater in healthy than in pathological subjects (AN CV: 3.74±0.86 m/s, CO CV: 5.28±1.07 m/s, $p=0.004$; AN CV rate of change: 0.006±0.015 m/s^2, CO CV rate of change: -0.006±0.007 m/s^2, $p=0.006$, mean±SD). Contrary to expectations, MNF rate of changes in the AN group (-0.35±0.16 Hz/s) was found greater than in the CO group (-0.17±0.13 Hz/s, $p=0.004$, Mann Whitney U test, mean±SD).
CONCLUSIONS: CV findings were compatible with a predominance of type I fibers (and/or with an ipotrophy of type II fibers) and also with a lower subcutaneous tissue thickness with respect to CO group, as described in the literature with this pathology. Moreover, findings about MNF suggest an altered central control strategy aimed to increase mechanical force output increasing the level of synchronization of motor units. This study confirms the capability of sEMG to assess muscle condition during severe malnutrition suggesting further studies aimed to assess if sEMG can be used to monitor the effect of re-feeding and rehabilitation treatments.

T11.P09
INSTRUMENTED STRETCH REFLEXES OF FLEXOR CARPI RADIALIS AND FLEXOR CARPI ULNARIS MUSCLE

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AIMS: The stretch reflex delay and the Ca^{++}-saturation time of the flexor wrist muscles are two parameters of a system identification model, applied to estimate the reflexive mechanical stiffness of the wrist in patients with spasticity. The parameters can be estimated alternatively by means of (stretch) reflex measurements and can either be used to reduce the solution space for model identification or to verify the estimated parameters during system identification. In this study we analyse the magnitude and variability of both parameters, recorded in our instrumented setting.
METHODS: With their right hand, healthy subjects (9 male, 4 female, age range: 23-58) applied a 1 N flexion force onto a joystick that rotated around an axis that was aligned with the wrist. In 5 series, 65 stretch reflexes were provoked by 5° extension rotations.
Bi-polar surface EMG recordings (inter-electrode dist. 1 cm, band-pass: 20Hz-450 Hz, sample frequency 5000 Hz) from the Flexor Carpi Ulnaris (FCU) and Flexor Carpi Radialis (FCR) were obtained at 6 electrode positions with an inter-electrode distance of 3 cm longitudinally arranged on the muscle belly.
The stretch reflex delay was off-line estimated by cross-correlation with the positive wrist velocity profile; Ca^{++}-saturation time was estimated from the minimum to maximum reflex time within the muscle.
RESULTS: The longitudinal saturation time, recorded within the interval of 6 electrodes was FCU: 3.8 ms (SD 1.9) and FCR: 4.8 ms (SD 2.9) which coincides with an average muscular conduction velocity of respectively 39.5 $m.s^{-1}$ and 31.3 $m.s^{-1}$, which exceeds exceeds muscle fibre conduction velocities and which seems to result from a high pennation angle. The average stretch reflex ranges from 25 ms proximal to 30 ms distal of both FCU and FCR with large inter-individual differences (Figure 1).

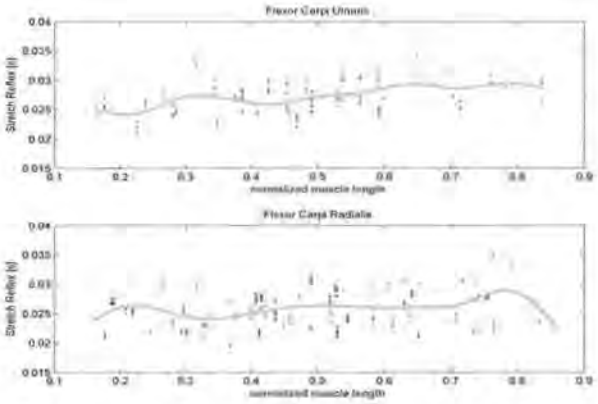

Figure 1. Individual stretch reflex times (colored dots) for FCU (top panel) and FCR (bottom panel) along the normalized muscle length including (grey) average reflex time.

CONCLUSIONS: In our instrumented setting we were able to provoke individually reproducible Stretch Reflexes in the FCU and FCR, though with large inter individual variation. The average Stretch Reflex time is relatively constant over the muscle and thus the saturation time is short. Methodologically, the Stretch Reflex time delay is relatively insensitive for electrode position and the saturation time can be lumped to the Stretch Reflex time. Clinically, the explaining structure of muscle fibres and innervation zone is important in relation e.g. to neuromuscular interface blocking (eg by Botuline Toxine) and needs further analysis.

T11.P10
PHASE AND FREQUENCY COORDINATION REPAIR IN THE INJURED OR MALFUNCTIONING HUMAN CNS BY COORDINATION DYNAMICS THERAPY

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MOTIVATION: It has been shown with surface electromyography (sEMG) and the single-nerve fibre nerve fibre action potential recording method that the neurons in the human central nervous system (CNS) organize themselves by phase and frequency coordination (1,2). This relative coordination becomes impaired following CNS injury, malformation or degeneration. A movement therapy, called coordination dynamics therapy, has been developed to improve coordinated firing of neurons and neural ensembles (premotor spinal oscillators), and to improve coordinated arm, leg, and trunk movements and vegetative (continence) and higher mental functions in patients with pathologic CNS functioning.
METHOD: For analyzing human CNS functioning sEMG and the single nerve fibre action potential (AP) recording method (to record from cauda equina nerve root fibres) were used. Coordination dynamics therapy is a movement learning therapy in which coordinated movements, automatisms, rhythmic dynamic stereotyped movements, and old learned movements are trained. In addition to functional CNS repair also a structural repair is possible by pushing during therapy the patient to his limits by performing 20 to 30 hours therapy per week. The improvement of CNS functioning is measured by the coordination dynamics (Kinesiology method), the improvement of movements and sEMG.
RESULTS: Substantial improvement in CNS functioning was achieved by coordination dynamics therapy in patients suffering stroke (3), traumatic brain injury (4), spinal cord injury (5), cerebral palsy, and Parkinson's disease (6).
CONCLUSION: With coordination dynamics therapy a therapy method is available to repair pathologic CNS organization based on functional (improvement of phase and frequency coordination between neuron firing and arm and leg movements, ...) and structural repair.

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Physical Medicine and Rehabilitation

SEMG UTILIZATION IN THE PHYSICAL MEDICINE AND THERAPY CONTEXT

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Surface electromyography (SEMG) is an electro-physiologic technique well adapted for research and clinical applications in the neuromuscular field.
The physiatrist and the physical therapist need to have objective knowledge of normal and abnormal muscular function within the context of joint and primary myotatic unit investigation and rehabilitation. For that purpose, it is necessary to conduct standardized SEMG dynamic protocol investigations which encompass the range of motion (ROM) testing of the primary myotatic units of the major and minor joints.
The author has tested over 6500 muscles with SEMG dynamic protocols in the amplitude domain through the (1) resting values and (2) the activity values involved at the minimal voluntary contraction (MVC) level through the ROM of the primary and secondary joints.
The statistical data has been presented and published in several textbooks and peer reviewed articles.The database derived from those studies can help identify the expected values of muscular activity amplitude potentials around different joints in the asymptomatic and symptomatic individuals.
Furthermore, the data can be organized to direct the temporal sequence of neuromuscular rehabilitation/retraining. Such organized rehabilitation program can facilitate the effort of the individual needing the rehabilitation program not only within the SEMG neuromuscular context but also in the context parameters of strengthening, agility, strength and endurance.
The SEMG dynamic testing can provide the sequence of amplitude potential values for any given set of segments of motion of muscles around a target joint. The sequence can then be reorganized according to the magnitude of the potentials, 'from low to high', i.e. from the motion requiring the least amount of energy/electrical effort onward to the one requiring the most energy. It stands to logical reason as well as to clinical practice that one would fatigue less and not so early while performing motions that require little effort, rather than from movements requiring a high level of effort. The sequence of muscular retraining is thus established and the patient is then taught the rationale of the program to follow.
The author will present the tables and graphics of the database for the primary myotatic units for all the major joints and the evolving rationale of the sequential rehabilitation.

TIME COURSE OF MUSCULAR, CONNECTIVE TISSUE AND NEURAL ADAPTATIONS TO UNILATERAL LOWER-LIMB UNLOADING

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Unloading of the musculoskeletal system leads to muscle wasting and weakness both in humans and in lower mammals [1]. Although the mechanisms behind the loss in muscle function are not fully understood, muscle atrophy only partly explains the decrease in maximal voluntary strength [2]. Recently, simulated microgravity has also been shown to leads to tendinous adaptations [3] represented by a decrease in tendon stiffness. This phenomenon could potentially contribute to the loss of muscle function by affecting the length tension relationship of the muscle-tendon unit. Although the quantitative changes of muscle mass to unloading are reasonably well known, the question of whether these adaptations precede, follow, or take place pari passu with those of the tendon has never been addressed. Hence the appreciation of the size and speed of the changes affecting both tissues seems fundamental to understand the mechanisms involved in muscle weakness associated with prolonged inactivity.
METHODS: In the present study, neuromuscular and tendinous adaptations to 23 days of unilateral lower limb suspension (ULLS) were assessed in 9 healthy men (aged 18 to 20 yr). Measurements were performed on day 14 and 23 of ULLS.
RESULTS: Knee extensors (KE) MVC, measured at 80 deg (optimum angle) of knee flexion, decreased by 25% ($p<0.001$) within 14 days of ULLS and did not decrease thereafter. Maximal voluntary activation, based on twitch interpolation, decreased by 4.1% ($p<0.05$) after 14 days and did not decrease thereafter. KE CSA, determined by magnetic resonance imaging at the distal 6/10 of femur length, decreased by 8.1% ($p<0.001$) after 14 days and by 14.0% ($p<0.001$) after 23 days. Patellar tendon stiffness and Young's modulus decreased by 21.1% and 21.5% ($p<0.05$) respectively, after 14 days and by 39% and 41% ($p<0.05$) respectively, after 23 days. The similarity between changes in tendon stiffness and Young's modulus indicated that the deterioration in tendon stiffness was due to changes in tendon material and not dimensions. Expressed as rate of daily loss, the decline in tendon material properties (Young's modulus) was 1.8%/day compared to a rate of loss of KE CSA of 0.6%/day. The results show that muscle atrophy and decreased activation accounted at best for ~3/4th of the decrease in torque, while the decrease in tendon stiffness accounted mainly for the remaining loss of MVC by having the muscle fascicles operate on a shorter length.
CONCLUSIONS: In essence, these findings indicate for the first time that the tendinous adaptations to unloading are about three times faster than those of skeletal muscle.We expect these diverse time courses to be reflected in differences in collagen and myofibrillar protein synthesis rates which are currently being investigated.

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EFFECT OF ABDOMINAL BRACING AND ABDOMINAL HOLLOWING MANEUVERS ON THE CONTROL OF SPINE STABILITY

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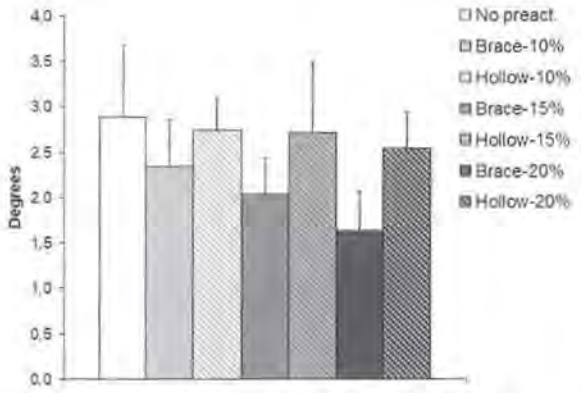
AIMS: Much discussion exists about which is the most effective maneuver or exercise to improve the stability of the spine. In this study, a sudden load paradigm was used to compare the effect of two popular stabilization maneuvers, abdominal bracing and abdominal hollowing, on control of spine motion and stability.
METHODS: Eleven healthy male individuals sat, torso upright, in an apparatus designed to foster a neutral spine position. Using an EMG biofeedback system the participants were instructed to perform abdominal bracing and hollowing maneuvers at three levels of internal oblique activation (10, 15 and 20% of MVC). Either resting (no preactivation) or performing the muscle activation maneuvers, they were rapidly posteriorly loaded. The muscular preactivation of seven trunk muscles (bilaterally registered) and the applied force were recorded; the torso muscular and kinematic responses to rapid loading were measured; and the spine stability and compression at L4/L5 were modeled.
RESULTS: For the same levels of internal oblique activity, abdominal bracing produced more torso coactivation, spine stability and compressive force than abdominal hollowing. Moreover, for the abdominal brace conditions, increasing the preactivation level significantly reduced trunk movement after sudden unexpected loading (Figure); however, no statistical

differences were found between any of the hollowing conditions and the no preactivation condition. Interestingly, for the 10% of internal oblique MVC, abdominal bracing and abdominal hollowing respectively resulted in reductions of 18.8% vs. 5.1% of lumbar extension, increases of 39.6% vs. 8.7% in spine stability, and increases of 52.1% vs. 42.1% of lumbar compression. As a general trend, the muscular response amplitudes of rectus abdominis, external oblique, latissimus dorsi and erector spinae at T9 and L3 were higher for the hollowing conditions than for the bracing conditions at each level of internal oblique preactivation.



Averages and standard deviations of the lumbar spine extension resulting from rapid posterior loading

CONCLUSIONS: The bracing maneuver fostered torso cocontraction, increased trunk stability and reduced the necessity for sophisticated muscular responses to rapid posterior loading, but at the cost of increasing spinal compression. On the basis of our findings, the hollowing maneuver does not directly enhance stability.

MODULATION OF CORTICOSPINAL EXCITABILITY FOLLOWING MOTO IMAGERY TRAINING OF KNEE EXTENSION

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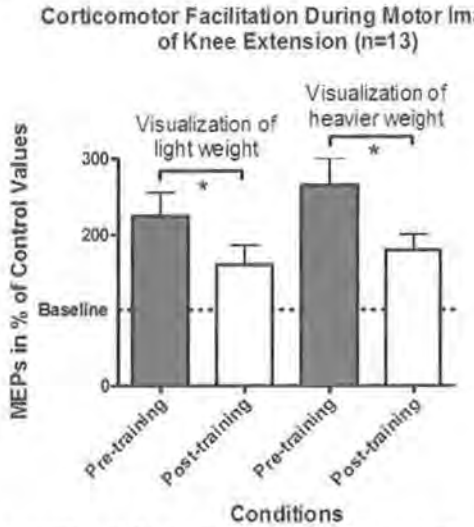
Motor imagery is a mental process involving the creation of an internal image of a task or movement that does not involve peripheral afferents or efferents. This technique is being used more frequently in rehabilitation.

AIMS: 1) To measure the cortical activity during mental imagery of a knee extension (movement with a light (LR) or heavy (HR) resistance; 2) to determine the effect of mental imagery training (home program: 5x10 repitions/day with HR for 7 consecutive days) on cortical activation and muscle strength.

METHODS: 13 healthy females (21.5±2 yrs) participated in this study. Corticospinal excitability was measured using motor evoked potential (MEPs) induced by transcranial magnetic stimulation (TMS) (Magstim 200 with double coil). The MEPs were recorded on the motor point of the quadriceps femoris (QF) of the dominant leg using EMG surface electrodes. MEPs were collected before, during and after each imagery task in pre and post training situations. The mental imagery vividness questionnaire (VMIQ, maximal score=120), the perception of the clarity of the imagined task (assessed with a visual analogue scale, VAS) (0-10 cm, 10=very clear) and the muscle strength of the QF (assessed with a Nicholas dynamometer) before and after training were also measured.

RESULTS: T-test showed that the MEP significantly increased during the mental imagery of the knee extension movement with LR (225±30%, $p<.001$) and HR (265±35%, $p<.0001$). When the two tasks were compared, results showed that facilitation associated with the HR was significantly higher than the one associated with LR ($p<.05$). Analysis for the VAS before training showed that there was a significant difference between LR (6.7±0.5) and HR (8.0±0.4) as for the clarity of the mental imagery ($p<.02$). Training did not change muscle strength. Following training, the same pattern of facilitation was observed ($p<.05$). However, analysis showed that the facilitation was significantly lower in post-training when compared to pre-training ($p<.05$) (see Figure). Interestingly, the VMIQ improved significantly from pre (48.3±4.5) to post-training (44.0±4.4) ($p<.001$).

CONCLUSION: The modulation of corticomotor excitability was intensity dependent of the imagined task. The training was probably too short to induce a change in muscle strength. The smaller corticomotor facilitation following training could be explained by the fact that unfamiliar tasks tend to activate more importantly the motor areas than learned tasks do. These findings suggest a clinical implication in rehabilitation. It simple method of training, easy and non-cost way to activate motor cortex around 25% of activation during active knee extension.



Comparison of the mean changes in MEPs amplitudes in % of baseline in Pre and Post training in the visualization of knee extension (mean±SEM) ($p<0.05$)*

CORTICOMOTOR MODULATIONS FOLLOWING INDUCED AND VOLUNTARY KNEE EXTENSION EXERCICES

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It is well known that voluntary exercises (Samii et al., 1996, Norgaard et al., 2000) or electrical stimulation (ES) induced exercises (Tremblay et al., 2000, 2005, Ridding et al., 2001) modifies corticomotor excitability.

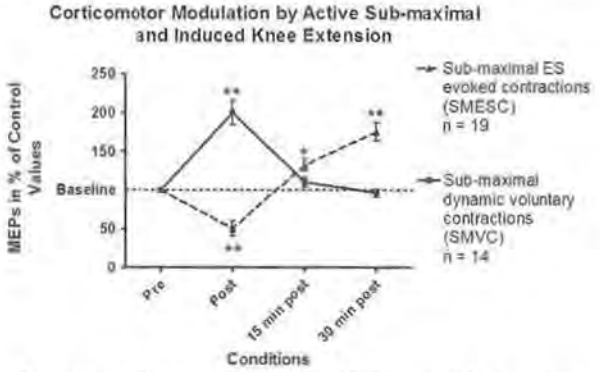
AIMS: The goal of this study was to determine the effect of voluntary and evoked exercises (ES) on the corticomotor pathways associated with the quadriceps femoris.

METHODS: 52 Healthy male subjects (mean, 22.9 ± 1.8 yrs) participated in the study. Corticomotor excitability was measured at different time after the exercises using transcranial magnetic stimulation (TMS) (Magstim 200) in four conditions: 1) sub-maximal dynamic voluntary contractions (SMVC), 2) sub-maximal ES evoked contractions (SMESC), 3) maximal voluntary isometric contractions until exhaustion (MVC), 4) maximal ES evoked contractions (MESC). The M-response and the perception of fatigue assessed by the Borg Fatigue Index (0-10, 10=extreme fatigue) (BFI) were also measured before and after each experimental condition.

RESULTS: When compared to baseline, ANOVA showed a significant MEP facilitation immediately following SMVC (200 ± 16%, $p<0.01$). M-response was unchanged ($p>.05$) and the BFI

score very low (1.1±0.2). SMESC was associated with a MEP depression immediately following evoked exercises (50±10%, p<.05). However, this depression was followed by an important facilitation 15 (132±8%, p<.05) and 30 minutes (175±12%, p<.01) following the end of evoked exercises. M response was unchanged (p>.05), and the BFI remained low (2.2 ± 2.0) (see Figure). MVC reduced the MEP immediately (70 ± 10%, p<0.05), as well as at 15 (45±6%, p<.05) and 30 minutes (40±12%, p<.05) following exercises.The M response was reduced only for the first 5 minutes (65±10%, p<.05) and the BFI was high (8.2±0.5). MESC produced a significant MEP reduction immediately (40±8%, p<.05) as well as 15 (35±8%, p<.05) and 30 minutes (30±6%, p<0.05) following evoked exercises. The M response was reduced only for the first 5 minutes (55 ± 6%, p<.05) and the fatigue level was mild (3.5±2.5).

CONCLUSIONS: Sub-maximal voluntary and evoked exercises (SMVC and SMESC) were both associated with post-exercise facilitation (PEF) but at different time periods (early for SMVC and later for SMESC). On the opposite, the MVC and MESC induced a central fatigue that lasted more than 30 minutes. Those results suggest that voluntary and evoked sub-maximal exercises are preferable for the rehabilitation of clients with paretic muscles and that the combination of those two exercises represents a new and promising strategy.



*Comparison of the mean changes in MEPs amplitudes in various conditions (Mean± SEM)(*P<0.05, **P<0.01)*

KNEE AND ANKLE EXTENSORS COACTIVATION DURING GAIT IS RELATED TO DEFICIENT SPINAL MODULATION IN HEMIPARESIS

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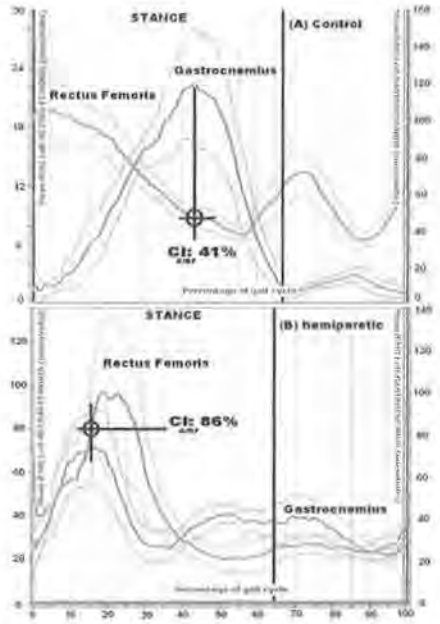
AIMS: Spinal circuits between knee and ankle extensors motoneurones are thought to assist bipedal stance and gait.These neural circuits are explored by measuring the femoral nerve (FN) stimulation induced facilitation (latency: 26 ms; duration: 8 ms) and the consecutive inhibition (latency: 34 ms; duration: 60 ms) of soleus (Sol) reflex and voluntary activities (Forget et al., 1998). Impairment of this spinal modulation was correlated with spasticity in stroke subjects (Dyer et al., 2002).This present study assesses whether the abnormal coactivation of knee and ankle extensors in hemiparetic gait is related to the malfunction of these spinal mechanisms.

METHODS: Eleven controls (mean age: 45±13 years) and fifteen stroke subjects (51±16years) participated in this study.The spasticity level at the paretic leg was measured using a composite spasticity index. Intersegmental facilitation and inhibiton were explored in sitting position by measuring the effects of FN stimulation (0,5 ms pulse; Hmax/2 at Q) onto triceps surae EMG at rest and at 30% of MVC. EMG activities of knee (RF: rectus femoris) and ankle (G: gastrocnemius) extensors were recorded in both legs during gait at a similar mean walking speed (0,85 m/s) in both groups. Mean coactivation indexes (CI) between RF and G were calculated from mean integrated EMG data of 9 gait cycles. CI represented the percentage of maximal RF activity during peak G activation.

RESULTS: At rest, during the facilitation period, from 22 to 35 ms after FN stimulation, there was a significant facilitation of Sol EMG in the hemiparetic subjects (median=+118%), but not in the control group (median=+40%). At 30% of Sol MVC, control subjects showed a significant inhibition of Sol EMG (-75%) from 48 to 61ms after FN stimulation. Hemiparetic subjects had less inhibition (-58%) and at later latencies (from 61 to 74 ms). During gait, greater CIs were observed at the paretic leg (CI=75%) in contrast to the non-paretic side (CI=55%) (p=0.037) and to either side of the control subjects (CI=40%) (p=0.024) (see Figure). Finally, the heteronymous facilitation of Sol at rest was correlated to the level of spasticity (Spearman Rho=0,68; p=0.005) and to the level of coactivation between G and RF muscles (Spearman Rho=0. 54; p=0.045) at the paretic side.



Differential pattern of activation of rectus femoris and gastrocnemius (mean iEMG traces ±SD of 9 gait cycles) during gait in a control (A) and a hemiparetic (B) subject

CONCLUSIONS: There is an increased facilitation and a decreased inhibition in the pathways from FN to Sol in spastic hemiparesis. The spasticity level and the abnormal coactivation of leg extensors during gait are correlated with this impaired modulation following stroke.

Meunier et al., (1996) Muscle Nerve. 19(9):1110-5.
Forget et al., (1998) ISEK Proceedings: 180-181.
Dyer et al., (2002) ISEK Proceedings: 387-388.

THE NOT INSIGNIFICANT ROLE OF BWS TREADMILL TRAINING IN IMPROVING COORDINATION IN LOWER MOTONEURON PATIENTS

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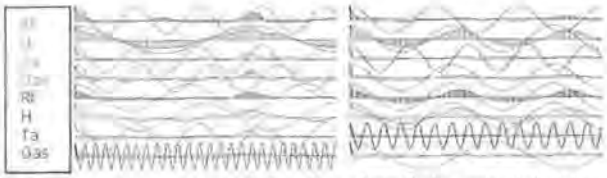
AIM: The study evaluated the differential effects of different amounts of body weight support in treadmill training (BWSTT) on the shank muscle activation pattern in clinically incomplete SCI patients during their early rehabilitation. It was hypothesized that the loading percentage of BWSTT would improve the coordination of muscle activation and decrease the clonus induced coactivation of the lower extremities.

METHODS: Three incomplete SCI patients with (>2 months) complete para/tetraplegia with high muscle tonus were selected. According to ASIA (American Spinal Injury Association) classification, two (Patients 1 and 2) were ASIA A (sensory and motor complete) with a C3-4 lesion level and one (Patient 3) was ASIA B (sensory incomplete and motor complete). The patients were treated with BWSTT over a three-month period. Measurements were taken one, two, and three months after admission. During treadmill walking, the surface EMGs of the right and left leg muscles [rectus femoris (RF), biceps femoris (H), tibialis anterior (TA), and lateral gastrocnemius (LG)] were recorded. The training program consisted of two-three treatments a week, 45 minutes each. Speed, % BWS, and total time were chosen as indicators of an improvement in gait tolerance. For data analysis, the EMG was rectified: it was averaged and normalized in time over 10 gait cycles. The auto-correlation and shifted cross spectra was calculated for all the antagonistic pairs.
RESULTS: The overall speed and time endurance of the gait training sessions improved over testing sessions. All patients required less body weight support over time, exhibiting a reduction in % BWS. The observed trend was of a shift from co-contraction to a reciprocal activation pattern in the thigh muscles (RF,H), with an unchanging pattern of co-contraction in the ankle muscles (TA,LG) especially during the swing phase.
CONCLUSIONS: The transition to a more reciprocal EMG pattern occurred especially in the thigh muscles and ahead of the shank muscles. The latter remain under the influence of peripheral sensory reactions. If we can determine how to impose plasticity on the central pattern generators, we may be one step closer to leveraging treadmill training to accelerate and/or resolve spastic clonic behavior in incomplete SCI patients.



Representative auto correlation data along 8 channels (1-4 right side, 5-8 left side) from Patient 1 during the first (A) and last (B) testing sessions

DIFFERENCES IN MUSCLE ACTIVATION PATTERNS DURING WALKING BETWEEN CHRONIC LOW BACK PAIN PATIENTS AND CONTROLS

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AIMS: Different models have been postulated to understand the development and maintenance of chronic complaints after an initiation of pain. Some of these models are more physiological (e.g. Johansson, 1991; Lund, 1991) whereas others are more psychologically orientated (e.g. Vlaeyen, 1995; Hasenbring 2001). All models have in common that motor control, as reflected in sEMG patterns changes, but in most cases a different task related behaviour is predicted.
The aim of the present study was to get more insight in the differences in sEMG patterns of trunk muscles between patients with chronic low back pain (CLBP) and healthy controls during walking at different velocities. The patient group was analyzed groupwise but in addition a analysis was made in a subdivision of patients with low versus high fear of movement was made.
METHODS: In a cross sectional study twenty-two patients with CLBP and eleven healthy controls were included. They walked at different velocity (from 1.4 km/h, with an increase of 0.8 km/h each trial, until finally 5.4 km/h) on a treadmill. Kinematic data of trunk and lower extremities was obtained using a optical three-dimensional gait analysis system (VICON 370), and simultaneously sEMG data of trunk muscle (erector spine L1 and L4, rectal and external oblique abdominal muscle) were obtained using a 16 channel surface EMG (Glonner) system. Fear of movement was measured with a questionnaire; the Tampascale (TSK). Smoothed rectified EMG (SRE) patterns were calculated per gait cycle and averaged but SRE values were also calculated separately for the four phases of the gait cycle (first double stance, first single support phase, second double stance phase and second single support phase).
RESULTS: Significant higher SRE values were found in patients compared to controls for each muscle. The relationship between SRE and velocity is characterized by a hyperbolic curve. This curve is most obvious for controls with the lowest SRE values at 2.2 km/h, probably representing the optimal walking speed. Patients showed a less clear hyperbolic curve. Analysis of the four gait phases, shows that the differences between patients and controls are most evident during the double stance phase.
Subdivision of the patients based on level of fear of movement, shows significantly higher SRE values for all back muscles (except ES L4 left) in patients with low fear of movement. For the abdominal muscles higher values were found in patients with high fear of movement (except RA left). Both groups show more sEMG activity in comparison with controls.
CONCLUSIONS: The overall higher levels of sEMG in patients compared to controls are in line with the pain-spasm-pain model (Johansson, 1991). However the differences in sEMG between patients with differences in psychological factors plead in favour of the model of Hasenbring and indicates that in different subgroups of patients different motor control mechanisms might play a role in the maintenance of their chronic pain.

EXTRACTION OF DISTINCTIVE COMPONENTS OF MOTOR CONTROL FROM SURFACE EMG IN HEALTHY AND SPINAL CORD-INJURED PATIENTS

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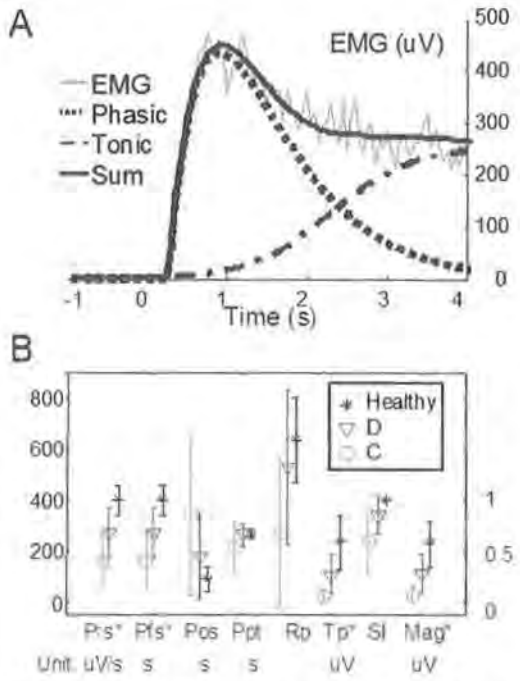
AIMS: Multi-muscle surface electromyography (sEMG) has long been applied for assessing motor control in health and disease. However, an accepted objective method to quantify voluntary motor control is still lacking. Voluntary Response Index (VRI) has been proposed as a measure of activation patterns across multiple muscles (Lee et. al. 2004), but it does not specifically address temporal activation of the agonist muscle during single joint movement. We describe here a curve fitting method based on two functions representing phasic and tonic component of sEMG. Parameters describing the two functions are expected to be altered after central nervous system injury. Therefore, we hypothesize that significant differences will emerge between healthy and distinct groups of spinal cord-injured (SCI) patients.
METHODS: sEMG was recorded from 15 neurologically intact subjects and 61 SCI patients using a standardized protocol ("Brain Motor Control Assessment"). The severity of SCI was classified according to the American Spinal Injury Association Impairment Score (AIS); 27 AIS-C and 34 AIS-D. sEMG was bilaterally recorded from quadriceps, adductor, hamstring, tibialis anterior (TA) and triceps surae muscles. Full bandwidth data was reduced using a root mean square (RMS) algorithm to produce sEMG envelopes (sampling rate 20/second). sEMG of the TA muscle during voluntary ankle dorsiflexion was fitted using phasic (linearly-rising slope with exponentially falling curve) and tonic (scaled sigmoid curve) functions. The parameter of these functions, and previously described Similarity Index (SI) and EMG magnitude, were compared between healthy, AIS-C, and AIS-D subjects.
RESULTS: sEMG from TA muscle during 4-sec activation (Figure A) was reconstructed by summating phasic and tonic functions

(power error 1.9±0.9% for healthy, 4.6±6% for AIS-D, 9.2±15.3% for AIS-C). The following parameters were significantly different between three groups (ANOVA): phasic function- rising slope, falling slope, tonic function- peak, and EMG magnitude (Figure B).
CONCLUSION: sEMG of the TA muscle during ankle dorsiflexion could be reconstructed by the two functions representing phasic and tonic components with <10% error in power. Some of the parameters of these functions distinguish activity in agonist sEMG between the groups. Therefore, the shape of sEMG envelope contains motor control features related to injury severity. The characteristics of the sEMG trace can be objectively extracted by curve-fitting technique with analytic functions.



A: sEMG was fitted by the summation of phasic and tonic functions. B: Mean ± SD for each parameter across three groups. Prs (Phasic rising slope), Pfs (Phasic falling slope), Pos (Phasic onset time), Ppt (Phasic peak time), Rp (Phasic/tonic peak ratio), Tp (Tonic Peak), SI (Similarity index), Mag (EMG amplitude). Star (*) indicates significant difference (p<0.05) between three groups

MUSCLE ACTIVATION PATTERNS DURING INDEPENDENT AND GRAVITY-COMPENSATED REACH AND RETRIEVAL MOVEMENTS IN ELDERLY PERSONS

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AIM: In stroke, coordination of movements is often impaired, for example abnormal muscle synergies are present frequently (Dewald 1995). Instantaneous reduction of these abnormal synergies in both static and dynamic reaching has been achieved by the use of compensation of gravity for the arm, as measured by joint torques (Beer 2004, Sukal 2005). As such, this could be a good method to train upper limb coordination after stroke. However, little is known about the effects of compensation of gravity on muscle activation patterns in stroke patients, as well as in healthy persons. The aim of this study is to examine muscle activation patterns with and without compensation of gravity during reach and retrieval in healthy elderly persons.
METHODS: Using a cross-sectional design, 10 healthy elderly subjects performed standardized, horizontal reach and retrieval movements, independently and gravity-compensated, in three directions. Muscle activation patterns were quantified using surface electromyography (EMG) and joint angles. Bipolar EMG was recorded from biceps (BIC), triceps (TRI), anterior (DA), middle (DM) and posterior (DP) deltoid and upper trapezius (TRA) muscles. Signals were sampled at 1000 Hz, band pass filtered (10-400 Hz), rectified and smoothed for analysis (SRE). Individual muscle activation patterns were generated by averaging SRE traces over all repeated movement cycles. Intra-subject changes in EMG intensity with gravity-compensated movements were calculated using Root Mean Square (RMS) values and tested statistically.
RESULTS: By superimposing individual SRE traces, generic aspects of muscle activation patterns for independent reach and retrieval movements were extracted. The aspects for reaching comprise continuous DA activity to elevate the arm; decreasing BIC activity to extend the elbow and increasing DP activity to control movement of the arm on approach of the target. Generic aspects for retrieval consist of increasing DP activity to retract the arm; decreasing BIC activity to extend the elbow and increasing DA activity to control movement of the arm on approach of the target. TRI activity is very low during reach and retrieval, since active elbow extension is not necessary. TRA and DM assist in elevating the arm during reach and retrieval in various degrees across subjects. Differences with compensation of gravity are most evident in BIC, DA and TRA: these muscles had lower RMS values during gravity-compensated movements in a majority of subjects during both reach and retrieval ($p<0.019$). More ambiguous results across subjects are seen in TRI, DM and DP.
CONCLUSIONS: Generic aspects of muscle activation during reaching and retrieving by healthy elderly persons could be distinguished. The most consistent patterns in muscle function across subjects were seen in BIC, TRI, DA and DP (functioning as agonist as well as antagonist). Compensation of gravity reduced the amount of muscle activity, predominantly in anti-gravity muscles (BIC, DA, TRA). These findings provide a good starting point to study facilitation of arm training in stroke patients using gravity compensation, allowing for example a longer training duration.

TRUNK MUSCLE RECRUITMENT IN LOW-BACK PAIN PATIENTS, DIFFERENT ADAPTATIONS TO THE SAME PROBLEM

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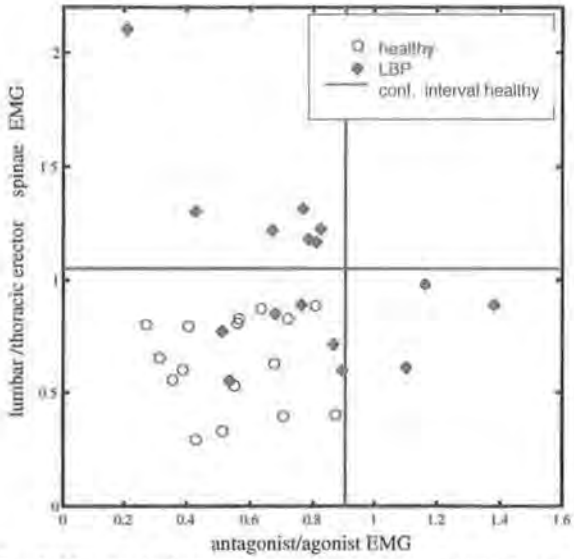
AIMS: We have previously shown that patients with low-back pain (LBP) use trunk muscle recruitment patterns that deviate from those in healthy controls. We had hypothesized that trunk muscle recruitment would be adapted in these patients to enhance spinal stability. We studied three adaptations that through numerical simulation were shown to enhance stability: increased cocontraction, preferential recruitment of lumbar extensors over thoracic extensors, and preferential recruitment of internal oblique over rectus abdominus. Significant differences between the patient and control groups were found for the first two patterns. However, it has been shown that the redundancy in the musculoskeletal system allows for different ways of enhancing spinal stability, suggesting that different patients may show very different adaptations of trunk muscle recruitment. The aim of the present study was to re-analyze the data summarized at an individual level using multi-variate statistics.
METHODS: Sixteen low-back pain patients and 16 matched control subjects performed slow trunk motions in each of three cardinal planes about the upright posture. Motions were performed with the thorax loaded with a 16 (for males) or 8 kg (females) weight vest and unloaded. For each of the 18 tests, ratios of EMG amplitudes of antagonist over agonist muscles and of lumbar erector spinae over thoracic erector spinae and of internal oblique over rectus abdominus were calculated over

a plus to minus 5 degrees range of motion. MANOVA and discriminant analysis were used to analyze the data.
RESULTS: The multivariate analysis illustrates that a linear combination of the three EMG ratios differentiates much better between patients and controls, than either ratio separately. In fact, in a stepwise discriminant analysis all three ratios contributed highly significantly to a function that classified subjects with 87.5% specificity and sensitivity. Different combinations of EMG ratios from the series of tests performed yielded similar quality classifications, but good classification always required a combination of the three ratios.
CONCLUSIONS: The results of the discriminant analysis indicate that to enhance spinal stability, some patients use cocontraction, while others use preferential recruitment of muscles strongly contributing to spinal stability. Furthermore, some overlap between the patients and controls was apparent. These between-subject differences may well account for the inconsistent results found in the literature. It is likely that the costs (e.g. increased energy expenditure and joint loading) of these adaptations as well as their adaptive value with respect to stability differ.



Two EMG ratios in flexion and extension movements in patients and controls. Data points right of the vertical and above the horizontal lines fall outside the confidence intervals of the healthy group

LUMBOSACRAL ORTHOSES REDUCE TRUNK MUSCLE ACTIVITY IN A POSTURAL CONTROL TASK

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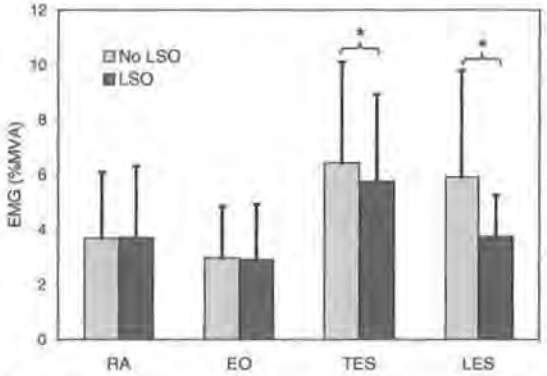
AIMS: Biomechanical modeling estimated that trunk muscle activity during various tasks could be reduced by 1-14% without the loss of spine stability when a lumbosacral orthosis (LSO) is worn (Cholewicki, JOR 22:1150-1155;2004). This reduction in muscle co-contraction could benefit patients with low back pain (LBP), who exhibit elevated muscular activity during postural tasks such as walking, standing, and sitting. The present study experimentally tested this theoretical prediction in an unstable sitting task.
METHODS: The task consisted of balancing on a seat supported by a plastic hemisphere (Ø=30 cm) and placed on a force plate to track the center of pressure (CoP). The average CoP velocity quantified the performance. Healthy subjects (12 males, 11 females) were asked to balance for 20 sec in 3 trials, with and without the LSO in random order. EMG was recorded bilaterally from rectus abdominis (RA), external oblique (EO), thoracic (TES) and lumbar erector spinae (LES), and expressed as the % of maximum voluntary activation (%MVA). ANOVA was used to compare muscle activity between the LSO and No LSO conditions.
RESULTS: There was no significant difference in the balance performance with and without the LSO. However, EMG averaged across the trials was significantly lower in the LSO than No LSO condition for TES (5.8±3.2 vs. 6.4 ±3.7% MVA, $p<0.02$) and LES (3.7±1.5 vs. 5.9±3.9% MVA, $p<0.01$). No significant differences were present in the abdominal muscle activity.
CONCLUSIONS: A significant reduction in the back muscle activity due to LSO was documented during an unstable sitting task. These results agree with spine modeling simulations, which predicted the greatest reduction in muscle activity to occur in TE and LE. Therefore, patients with LBP could benefit from wearing LSOs, which permit a slight reduction in trunk muscle co-contraction while maintaining spine stability. In turn, LSOs may prevent muscle fatigue and pain from compounding the existing pathology during acute stages of LBP.



Trunk muscle EMG (mean and standard deviations) during unstable sitting task. Asteriks indicate significant differences ($p < 0.05$)

RELIABILITY OF POSTURAL STABILITY MEASURES IN PATIENTS WITH CHRONIC IDIOPATHIC LOW BACK PAIN

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AIMS: An increasing number of studies have identified balance impairments in patients with chronic low back pain (cLBP), with many possible causes suggested. Furthermore, evaluation of postural stability has been repeatedly suggested as being both a valuable functional diagnostic and treatment monitoring tool in these patients. Such theory, however, does not seem to be well supported as there is a lack of evidence of whether posturographic measures recoded from cLBP patients are reliable and therefore clinically and scientifically useful. In order to fill this gap, this study investigated both the short and the long term reliability of postural stability measures in cLBP patients.
METHODS: A total of 33 cLBP patients with a mean age of 44 (9.4) years completed quantitative posturography (Equitest, Neurocom International, Clackamas, Oregon) to determine the subjects response to sensory (Sensory Organization Test, SOT) and motor perturbation (Motor Coordination Test, MC). The SOT comprised measures in an upright standing position with eyes opened or closed on hard or soft surface and surroundings fixed or moving. The MC tasks were external perturbations using both translation and inclination in the anterior posterior direction. Subjects completed the tests three times within a day and repeated the whole series of experiments 3 weeks later. All subjects were free from centrally active medication and did not receive treatment between the two experimental days. The Postural

Stability Index, which is defined as the percentage ratio of the destabilizing torque due to gravity and the stabilizing torque due to the ankle muscles were calculated for each of the conditions. From the postural perturbation tasks mean latencies (ms) of mechanical postural reaction times were calculated. At the beginning and at the end of each experimental day subjects completed various VAS scales that assessed pain and personal feelings and fear associated beliefs. All these VAS tests were related to the postural examination tests.

RESULTS: The intra class correlation coefficients of the different posturographic test conditions revealed results that indicated fair to excellent short and long term reliability. Long term retesting of the more challenging conditions of the SOT with surroundings and/ or surface fixed or moved demonstrated significant changes in the mean of the respective indices. VAS ratings of pain, feelings and fear associated beliefs were not related with these longitudinal changes.

CONCLUSIONS: Our findings suggest that postural stability measures are clinically reliable in cLBP patients. However, as some of these measures demonstrated significant learning effects for the SOT conditions, their clinical application may be of limited value in rehabilitation everyday practice.

Key Words: Low back pain, postural equilibrium, reliability

TRUNK MUSCLE ACTIVITY IS INCREASED DURING EXPERIMENTAL BACK PAIN, BUT THE PATTERN VARIES BETWEEN INDIVIDUALS

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AIMS: Low back pain is associated with changes in control of the trunk muscles, but the nature of this change has been debated with authors citing both increased and decreased activity. However, most studies have recorded from a small subset of muscles and have not been able to determine whether the activity is changed relative to pre-pain values. The aims of this study were to investigate changes in activity of 12 trunk muscles around the neutral position during experimental pain, and to investigate differences in the pattern of change in trunk muscle activity between individuals.

METHODS: Electromyographic activity (EMG) of 3 trunk flexor (rectus abdominis (RA), obliquus internus (OI) and externus abdominis (OE)) and 3 trunk extensor (thoracic (TES) and lumbar erector spinae (LES) and latissimus dorsi (LD)) muscles was recorded bilaterally while subjects performed slow trunk movements between -20 degrees (extension) and +20 degrees (flexion) prior to and after the injection of hypertonic saline into the right longissimus, and after pain had resolved. Pain was reported on a 11-point numerical rating scale (NRS) anchored with "no pain" and "worst pain imaginable". Two trials each were perfomed in each direction. QRS complexes (heart beat artifact) were removed from the EMG using a modified turning point filter, data were rectified, low pass filtered at 1 Hz and the root mean square (RMS) of the 12 EMG signals was calculated at each angle. The minimum RMS EMG was calculated and the value for each muscle at this angle was recorded to assess the relative contribution of each muscle to the change in RMS EMG. EMG was defined to be increased or decreased if it changed by >15% from baseline values.

RESULTS: Subjects reported pain of 6.1(2.7) after saline injection. With movement from flexion to extension the minimum RMS EMG increased by 37(46)% during pain ($P<0.05$) and by 18(33)% ($P<0.05$) and when moving from extension to flexion. Minimum RMS EMG was increased during pain in 75% and 66% of subjects depending on the movement direction. After the pain had resolved, the minimum RMS EMG had returned to control values. When data were analysed for the group, EMG activity of TES was increased bilaterally ($P<0.001$) and that of OI was increased on the left (contralateral to experimental pain, $P<0.02$). However, there was considerable variation between individuals and no two subjects showed an identical pattern of increased activity. Left OI EMG was increased in 83% of subjects, left RA in 75%, and right OE and OI, and left LES in 67%. Left OE activity was reduced in 67% of subjects, and right OI and TES, and left RA and LES in 25%.

CONCLUSIONS: These data indicate that although experimental back pain was associated with variable changes in trunk muscle activity, there was a net increase in activity when all muscles were considered. This finding is consisitent with the proposal that the nervous system responds to pain by increasing muscle activity to protect the spine from the real or perceived threat of further pain or injury.

T12.P01
CORRELATION BETWEEN ELECTROMYOGRAPHIC AND ULTRASONOGRAPHIC DATA OF THE MASSETER MUSCLE IN CHILDREN

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AIMS: Understanding the relation between morphology and physiology of the stomatognathic system may contribute for a better planning of the orthodontic treatment and of the orofacial myofunctional therapy. The aim of present study was to analyze the correlation between the electromiographic active and the thickness of the muscles masseteres right and left.
METHODS: 60 leucoderm children from both genders, ranging in age from 6 to 9 years, with normal occlusion or with malocclusion were selected from an University clinic. All of them underwent odontologic, electromyographic and ultrasonographic clinical evaluation of the masseter muscles performed by an expert Professionals. The MyoSystem-Br1 was used, with differential active electrodes. The electromyographic recordings were done in the following clinical conditions: muscle at rest during (10 sec), at maximal voluntary dental clench (4 sec) with and without cotton rolls, gum, cereal bar, cookie and peanut chewing during (20 sec). The ultrasonographic recordings were done with a linear device of 7.5 MHz, connected to a echo camera (CS 9300, Picker International GmbH, Vienna, Austria), and the measures were registered on the screen with a variation of approximately 0,1 mm. The guidelines of the series of exam were based on the standardized protocol for obtaining a transversal cross-section perpendicular to the muscle's axis. Each muscle exam was done at rest and during maximal clenching; the average of repeated measures in each condition was considered. The correlations were calculated using the Pearson's test (Statistics Software).
RESULTS: There were significant positive correlations between the thickness of the right masseter muscle, in cm, verified in the ultrasonography at rest and in the maximal dental clenching, and the electromyographic activity (RMS) in the following clinical conditions: maximal voluntary dental clench, chewing of cereal bar and cookies. The thickness of this muscle at rest was also correlated to the maximal voluntary dental clench activity with cotton and to the gum chewing. There was a significant positive correlation between the left masseter muscle thickness, in cm, at rest and during maximal dental clenching, and the electromyographic activity (RMS) in the maximal voluntary dental clench. The thickness at rest was also correlated to the maximal dental clenching with cotton ($p<0.05$).
CONCLUSIONS: Several clinical conditions of the electromyography were correlated to the masseter muscles thickness measured by the ultrasonography. Therefore, the results showed a relationship between the thickness and the function of the masseter muscles.

T12.P02
SURFACE EMG OF THE MASSETERS AND ANTERIOR TEMPORALIS MUSCLES AND CHEWING CYCLES IN CHILDREN WITH DEEPBITE

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AIM: The aim of the study was to investigate electromyographic (EMG) activity of the masseter and anterior temporalis muscles during chewing in children with deep bite as compared to healthy children.
METHODS: 39 children (age, mean±SD, 11.1±1.2 yr) with deep bite (Figure 1) and 33 children (age, 10.8±1.3 yr) with normal occlusion (control) participated to the study. EMG signals were recorded from the right and left masseter and anterior temporalis muscles and chewing patterns were concomitantly analysed with a kinesiograph (K6-I Myotronics Inc. Tukwila, WA - USA). The children were asked to chew a soft and a hard bolus in the following conditions: 1) non deliberately, 2) deliberately on the right, and 3) deliberately on the left side, for 10 seconds. Recordings in each condition were repeated three times in the same experimental session. Statistical analysis was preformed by repeated measures analysis of variance (ANOVA). EMG signals were rectified and filtered (cut-off frequency 10 Hz) to extract the signal envelope.
RESULTS: With both soft and hard bolus, the peak of EMG envelope was higher in the group of children with deep bite than in the control group for both the masseter ($P<0.01$) and anterior temporalis muscles ($P<0.05$). The angle of closure in the frontal plane was smaller (more vertical closure trajectory) in the group with deep bite than in the control group ($P<0.05$).
CONCLUSION: Muscle activity during mastication was found increased in children with deep bite with respect to controls. Moreover, angle of closure, which indicates the efficiency of the chewing cycle, was significantly different in the two groups. These results indicate that deep bite is not a simple malocclusion but it involves a reorganization of muscle activity during chewing. Thus, the correction of teeth position may not be sufficient for reestablishment of a normal chewing cycle.

Figure 1: Patient with Deep bite malocclusion (A) and with normal occlusion (B).

T12.P03
SPEECH FLUENCY PROFILE AND ELECTROMIOGRAPHIC ANALYSIS OF MASSETER AND TEMPORAL MUSCLES

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AIMS: To compare subjects with stuttering complaint and without speech complaint verified by the speech fluency profile, and the electromyographic activity of the masseter and temporal muscles.
METHODS: 10 individuals with stuttering complaint and 10 fluent speakers took part in this study; they were paired regarding gender and age, and the mean age was 13,4 years. The speech samples were analyzed according to the speech fluency profile evaluation of the ABFW - Language Test. In order to analyze the muscle activity, a K6-I EMG Light Channel Surface Electromyography (Myo-tronics Co. Seattle, WA, EUA) of eight channels was used. Double disposable electrodes of silver chloride surface were used (Duotrodes, Myo-tronics Co., Seattle, WA), with a conductor gel (Myogel-myo-tronics Co., Seatlle, WA). The electrodes were positioned on the masseter and on the anterior portion of the temporal muscles following the muscle fibers orientation. A reference electrode (ground) was positioned near the back of the patients neck. The patient remained sited in a comfortable chair, with the head positioned straight according to Frankfurt plan. The clinical conditions investigated were: muscle at rest; maximal voluntary dental clench, with and without cotton rolls; words and sentences utterance; cereal bar chewing; resting before and after the exercises, each task lasting 15". Eletromyographic data were normalized by maximal voluntary contraction during dental clenching. For the speech fluency profile comparison, the non-parametric test of Mann-Whitney was used and for the electromyographic activity, the t-Student test for independent samples was used.
RESULTS: There was a significant statistical difference between the groups concerning: the frequency of words repetition ($p<0.05$), total of stuttering-like disfluencies ($p<0.001$), syllables repetition, pauses, speech rate ($p<0.01$), percentage of speech disruptions, and percentage of stuttering-like disfluencies ($p<0.001$). There was no significant statistical difference between the groups regarding the electromyographic activity of the masseter and temporal muscles.
CONCLUSION: The speech fluency profile allowed to precisely characterize the groups in stuttering individuals and normal speaking individuals. Even considering the hypothesis that stutterers present some speech motor control dysfunction, the absence of significant differences between them and the normal speaking individuals regarding the electromyography suggests that the masseter and temporal muscles activity does not seem to be the differential parameter. A greater number of cases should be investigated in order to conclude something about the usefulness or not of orofacial relaxing exercises in the stuttering treatment.

T12.P04
MORPHOFUNCTIONAL COMPARISON OF CHILDREN WITH DENTO-ALVEOLAR AND SKELETAL ANTERIOR OPEN BITE

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AIMS: To compare individuals with dento-alveolar anterior open bite, with skeletal anterior open bite and without open bite through ultrasonography and electromyography of the temporal and masseter muscles.
METHODS: 51 leucoderm children, male and female, ranging in age from 6 to 9 years took part in the study, distributed in three samples: without open bite (control group), with dento-alveolar anterior open bite (DOB) and with skeletal anterior open bite (SOB), defined by clinical odontologic evaluation and lateral cephalograms. The ultrasonographic recordings were done with a linear device of 7,5 MHz connected to a echo camera (CS 9300, Picker International GmbH, Vienna, Austria). The guidelines of the series of exam were based on the standardized protocol for obtaining a transversal cross-section perpendicular to the muscle's axis. The exams were done at rest and during maximal clenching. The electromyographic recordings were done in the following clinical conditions: muscle at rest (10 sec); at maximal voluntary dental clench (4 sec) with and without cotton rolls; peanut, cereal bar, cookie, gum and damask chewing (20 sec). The Electromyographer MyoSystem-Br1 was used, with differential active silver electrodes. The groups were compared by the t-Student test for unpaired data (Statistics Software).
RESULTS: There were significant differences between the control and the DOB groups and between the control and the SOB groups regarding thickness and width of the investigated muscles, in cm, verified in the ultrasonography during rest and during maximal clenching ($p<0.05$). There was no statistical difference regarding the thickness or width between groups DOB and SOB. In the electromyographic activity (RMS) there were significant differences between the control and the DOB groups during rest and during peanut, cereal bar, cookie, chocolate and damask chewing, when comparing the left temporal muscles ($p<0.05$). There were also significant differences between the control and the SOB groups in the conditions of: maximal voluntary dental clench, regarding the left masseter muscle, the right and left temporal muscles; at rest and during chewing, regarding the left temporal and the left masseter muscles; and during cereal bar, cookies and gum chewing, regarding the left temporal muscles ($P<0.05$). There was no difference in the electromyographic activity between groups DOB and SOB ($p>0.05$).
CONCLUSION: In both evaluations, ultrasonography and electromyography, there were differences between the control group and the groups with open bite, but not between the groups with dento-alveolar open bite and with skeletal open bite in the age group studied; that does not eliminate the possibility of differences in future ages.

T12.P05
DISORDERS OF MASTICATORY MUSCLES BEFORE AND AFTER POSTERIOR CROSS BITE TREATMENT - EMG ANALYSIS

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AIMS: Early treatment of posterior cross bite can favor the harmonious grow and development of children. However, the functional impact of this treatment has not been evaluated. The aim of the present study was to evaluate the electromyographic active of right (RM) and left (LM) masseter and right (RT) and left (LT) temporal muscles of children presenting skeletal posterior cross bite before and after rapid maxillary expansion (RME).
METHODS: The sample consisted of 27 children, both sexes, between 7 and 10 years old. The treatment of posterior cross bite consisted of RME realized with the bonded maxillary expansion appliance, with was used during 4 months after the active phase. The electromyographic active was analyzed before treatment (T1) and after the appliance was removed (T2) during the clinical situation of rest (10 sec), maximal voluntary dental clench (4 sec) and habitual chewing (10 sec). The MyoSystem - Br1 electromyographer was used, with differential active electrodes. Electromyographic data were normalized by maximum voluntary contraction during dental clenching and the data were statically analyzed (SPSS 10.0 software). The differences between T1 and T2 data were evaluated using the paired t-test.
RESULTS: The differences between T1 and T2 was at rest: RM: 0.0429±0.0420 ($p<0.05$), LM: 0.05±0.10 ($p<0.05$), RT: 0.04±0.09 ($p<0.01$), LT: 0.04±0.08 ($p<0.05$); at habitual chewing: RM: 0.39±1.26, LM: 0.30±0.93, RT: 0.16±0.35 ($p<0.05$), LT: 0.23±0.41 ($p<0.01$), and at maximal voluntary dental clench: RM: 0.30±1.19, LM: 0.36±1.07, RT: 0.14±0.56, LT: 0.33±0.62 ($p<0.01$).
CONCLUSIONS: Based on this result and according to the used methodology, it could be concluded that the electromyographic active of masticatory muscles in children increased after posterior cross bite treatment.

T12.P06
RELATION BETWEEN RDC/TMD AND ELECTROMYOGRAPHY OF WOMEN WITH AND WITHOUT TEMPOROMANDIBULAR DYSFUNCTION

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AIMS: Regarding the presence of different literature dispositions concerning the masticatory musculature behavior in patients with Temporomandibular Dysfunction (TMD), the objective of this study was to compare the electromyographic activity of the masseter muscles and the anterior portion of the temporal muscles of women with and without symptoms of Temporomandibular Dysfunction.
METHODS: To accomplish this study eight women, aging between 22 and 46 years old, were selected, and they were divided into two groups according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/ TMD): - Group I: Women with myogenic TMD, who presented persistent facial pain, headaches and masticatory musculature pain during palpation; - Group II: Women without TMD who did not present pain. All volunteers performed electromyographic exam to analyze the muscular activity of masseter muscles and anterior portion of temporal muscles bilaterally, in which the rest signal was collected, and also the non-habitual masticatory activity of PARAFILM® (isotonic and isometric). A battery powered eight channel surface electromyograph was utilized with pre-amplified active electrodes, band pass filter with cut-off frequencies at 20-500 Hz, an amplifier gain of 1000x and a common mode rejection ratio > 120dB. The Test t was utilized for the statistical analysis of the data.
RESULTS: It was verified that the volunteers diagnosed with TMD based on the questionnaire presented muscular activity alteration. A difference was observed on the RMS (Root Mean Square) average values between Groups I and II regarding isotonic contraction (p=0,020158816) and isometric contraction (p= 0,020644963). However, there was no statistically significant difference (p=0,108950226) during rest.
CONCLUSION: It was noted a relationship between RDC/ TMD and the electromyographic exam, with statistically significant difference regarding the muscular activation pattern between dysfunctional women and those who did not present TMD.

T12.P07
ELECTROMYOGRAPHIC ANALYSIS OF THE MASTICATORY MUSCLES IN PATIENTES WITH TEMPOROMANDIBULAR DISORDER DURING CHEWING

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Temporomandibular disorders (TMD) are characterized by changes in masticatory musculature, temporomandibular joints and associated structures. The aim of this study was to evaluate masticatory function in TMD patients by means of surface electromyographic (EMG) exam, relating the TMD signs and symptoms to the lateral preference masticatory. Subjects were selected through an anamnesis, Questionnaire for Index and Diagnostic fulfillment and clinical exam recommended by Research Diagnostic Criteria for Temporomandibular disorders (RDC/TMD). Twenty seven female volunteers were selected, with 20-40 years old (25.03±5,22), divided in two groups, one constituted by TMD subjects (16 subjects) and another constituted by clinically healthy subjects (11 subjects). The EMG exam was carried out in the anterior portion of temporal and superficial part of masseter muscles bilaterally. The EMG recordings were acquired with single differential Ag/Ag electrodes (gain=20) in the Myosystem I® equipment, with a sampling rate of 2000 Hz, a 12 bits A/D card, gain of 150, 20 Hz high-pass and 500 Hz low-pass filters. The EMG signal was obtained in three different days, at the same time and with an interval of one week. The evaluation was accomplished during bilateral contraction and habitual mastication. The results showed that there was a relation between the side with the highest level of myoelectric activity and lateral preference masticatory in the clinically healthy group, but in the group of the TMD patients this relation was not observed, as in the habitual mastication as in the bilateral contraction. In TMD patients, the anterior portion of temporal showed the highest level of myoelectric activity in the lateral preference masticatory when compared with the superficial part of masseter muscles.

T12.P08
ELECTROMYOGRAPHIC ANALYSIS OF MASTICATORY MUSCLES OF ORTODONTICALLY TREATED PATIENTS, BEFORE AND AFTER OCCLUSAL ADJUSTMENT

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AIMS: Dentistry practice shows that innumerous orthodontic treatments are not finished in a satisfactory way, thus causing maxillomandibular glides/slides, i.e. a centric relation (CR) different from the maximal habitual intercuspation (MHI), which in turn may cause a unbalance of the condyle/articular disk set/ condyle/articular disk complex, and myofunctional changes and temporomandibular joint dysfunctions.
METHODS: This study aimed to assess the electromyographic activity of the temporal and masseter muscles of 10 patients, who after ending their orthodontic treatment presented mandibular glides/slide and a MHI different from the CR, and were submitted to occlusal adjustment due to selective wear. The electromyographic analyses were performed during chewing movements and while maintaining postural positions, before and after the occlusal adjustment therapy. An eight-channel electromyographer was used: K6-I EMG Light Channel Surface Electromyography (Myo-tronics Co. Seattle, WA, EUA). Paired T-test (SPSS 10.0) was performed for the comparison between the situations before and after therapy.
RESULTS: It was observed that, after occlusal adjustment, there was a tendency for the reduction of electromyographic activity during the maintenance of postural positions, while such activities were increased during chewing.
CONCLUSIONS: Therefore we conclude that, since occlusal adjustment therapy by selective wear reduces maxillomandibular glides/slides, it generates muscle relaxation that favors the activity of masticatory muscles during the chewing/masticatory cycle, and postural positions are maintained with a lower recruitment of muscular fibers and a greater balance of the condyle/articular disk set/condyle/articular disk complex.

T12.P09
CHANGES IN MASTICATORY MUSCLES ACTIVITY ASSOCIATED WITH EAGLE'S SYNDROME

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AIMS: This study had the goal of analyzing masseter and temporalis muscles of individuals with Eagle's Syndrome, establishing comparisons with healthy control individuals by means of electromyography, due to the importance of the masticatory musculature upon the various functions of the stomatognathic system and the effects of Eagle's syndrome on

this system's functioning.
METHODS: Ten women with Eagle's syndrome and ten healthy controls volunteered to participate in the study. A Myosystem I system, Prosecon Ltda (Uberlândia/MG, Brazil) with 12 channels was used. Active differential electrodes were placed on the belly of both masseters and on the anterior temporalis. Firstly, rest position was registered and then the patients were instructed to clench their teeth with maximum strength for four seconds to register the Clenching at Usual Maximum Intercuspation. Next, the clinical conditions of chewing, mandible laterality, and water swallowing were performed.
RESULTS: The normalized data of muscle activity during the different clinical conditions and at rest position were compared by Student's t test, considering two groups: controls and syndrome bearers. The masticatory muscles of every syndrome bearers showed hyperactivity during the analyzed clinical conditions; except for chewing, in which the right masseter did not show greater electromyographic activity.
CONCLUSIONS: It is concluded that individuals with the syndrome showed muscular hyperactivity when compared to healthy individuals, due to the interference of the elongated styloid process, which leads to dysfunctions of the stomatognathic system in the syndrome bearers, with signs and symptoms related to craniofacial pain, dysphagia, otalgy, temporomandibular dysfunctions, and headache.

T12.P10
THE CORRELATION BETWEEN ELECTROMYOGRAPHIC ACTIVITY AND BITING STRENGTH IN BRAZILIAN INDIANS (XINGU VILLAGES)

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AIMS: Preserving healthier life habits, as the ones kept by primitive populations, may generate a pattern of muscle activity different from those of civilized individuals. Hence, it is important to compare the data of electromyographic activity to the biting strength of indigenous subjects to know if there is a correlation, as occurs with civilized subjects.
METHODS: The electromyographic data of the right and left masseter and temporal muscles were collected during the maintenance of postural activities, chewing, and teeth clenching. Data for biting strength were obtained from the region of the incisive, premolars, and molars (right and left side). The study sample was composed of 13 indigenous subjects from the Xingu villages, and 13 civilized subjects (control group), with ages ranging from 17 to 30 years. A 12 channel Myosystem Br-1 electromyographer was used and the data were analyzed using SPSS software (Chicago) to perform the Pearson correlation test, with $p \leq 0.05$.
RESULTS: There were no statistically significant correlations among the electromyographic activities of the four muscles tested with the obtained biting strength values.
CONCLUSIONS: Therefore, indigenous subjects showed the same results as the civilized subjects, concerning the correlation between electromyographic activities and biting strength: such correlation does not exist.

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T12.P11
ELECTROMYOGRAPHIC COMPARISON OF MASTICATORY MUSCULATURE ACTIVITY BETWEEN BRAZILIAN INDIGENOUS MEN AND WOMEN AND CIVILIZED INDIVIDUALS

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AIMS: Modern life habits have brought new problems to dentistry, which demands for intensive investigations to control symptoms or the signs that are present in most of the modern population. Stress may cause temporomandibular dysfunctions and the collapse of stomatognathic system muscles, which generates contraction patterns different from those considered natural for humans. Currently, the study of primitive populations and comparing men and women subjects to civilized individuals may contribute to determining an initial pattern of muscle contraction of individuals who have not been exposed to stress factors and have healthy and natural eating and life habits.
METHODS: This study had the aim to compare the electromyographic activity of the temporal and masseter muscles during chewing and while maintaining postural movements, between 8 indigenous men and 7 indigenous women from the Xingu village, and between 8 civilized men and 7 civilized women (control group) with ages ranging between 17 and 30 years. An twelve-channel Myosystem Br-1 electromyographer was used, and the data was analyzed using SPSS software (Chicago). The differences between the normalized data were evaluated using the t- test.
RESULTS: There was a statistical significance for the comparison between indigenous men and women while maintaining protrusion (means: men=0.06, women=0.27, SE=±0.07), and for the comparison between control men and women while maintaining left laterality (means: men=0.06, women=0.13; SE= ±0.03) with $p \leq 0.05$. Either indigenous or civilized women showed greater activity than indigenous and civilized men during chewing and rest, whereas during dental clenching and chewing movements civilized women revealed a greater activity than control men, but indigenous women had a smaller activity as compared to indigenous men.
CONCLUSIONS: The data allow us to conclude that the noxious effects of modern civilization have a stronger influence on the female population, causing stress and an exaggerated recruitment of muscle fibers to perform a dynamic activity.

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T12.P12
THE EFFECT OF BRAZILIAN INDIANS' HABITS ON THE ACTIVITY OF STOMATOGNATHIC SYSTEM MUSCLES - ELECTROMYOGRAPHIC ANALYSIS

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AIMS: Brazil's modern population has frequently suffered from problems such as temporomandibular joint dysfunctions and the collapse of stomatognathic system muscles. Studying primitive populations, who maintain healthier habits, may be essential to discover a pattern of electromyographic contraction among those subjects, and to verify if modern habits do, in fact, interfere in stomatognathic system functioning.
METHODS: This study aimed to analyze the electromyographic activity, normalized by maximal voluntary contraction, of the temporal and masseter muscles during chewing and while maintaining postural movements in 15 indigenous subjects of the Xingu Village and 15 civilized subjects (control group) with ages ranging from 17 to 30 years. An twelve-channel Myosystem Br-1 electromyographer was used, and the data was analyzed using SPSS software (Chicago). The differences between the normalized data were evaluated using the t-test.
RESULTS: There was a statistical significance for the comparison

between indigenous subjects and controls during some of the dynamic activities, such as mouth opening and closing (electromyographic means: indigenous subjects=0.54, control= 0.16; EP=0.06) and chewing (electromyographic means: indigenous subjects=0.51, control=0.66) with p≤0.05.
CONCLUSIONS: We observed there was a lower electromyographic activity for indigenous subjects during chewing movements, which allowed us to conclude that primitive habits may maintain posture and generate chewing movements with a lower recruitment of muscle fibers, protecting the stomatognathic system from joint and muscular dysfunctions.

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T12.P13
EFFECT OF THE TREATMENT USING TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION, IN TEMPOROMANDIBULAR DYSFUNCTION PATIENTS

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AIMS: The aim of this work was to evaluate the effect of the treatment using transcutaneous electrical nerve stimulation (TENS), on the pain and on the electromyographic activity of the masseter muscle and of the anterior portion of the temporary muscle in TMD patients.
METHODS: Ten TMD female patients from 19 to 40 years of age (x=24,3±6,1) were selected as volunteers. To characterize the sample, Research Diagnostic Criteria for Temporomandibular Disorders was used; and 60% of the volunteers presented TMD of the group Ia, and 40% group IIa. The clinical index of severity of TMD classified the volunteers in severe TMD (40%), moderate TMD (50%), and light TMD (10%). The electromyographic evaluation of the masseter muscle and of the anterior portion of the temporary muscle was accomplished using the equipment Miosystem I® of 12 channels, with 12 resolution bites and active surface differential simple electrodes, with gain of 20 times. The signs were collected in sample frequency of 2KHz. In order to visualize and process the electromyographic sign, the program Myosystem I version 2.12 was used. Data normalization was accomplished using as reference value medium RMS of the base line, that consisted of three collections, in three alternate days, in a same week; always in the same period of the day. Nine TENS (biphasic symmetrical square pulse, 10 Hz, 200 µs, intensity in the motor threshold, and modulation in 50% of the frequency) applications were accomplished for 30 minutes; twice a week, with the electrodes positioned on the preauricular area and on the masseter muscles. The Visual Analogical Scale was applied before and immediately after each TENS application. Before the first treatment and before the tenth TENS application, the electromyographic exam was accomplished - in rest and voluntary contraction of maximum intercuspidation (VCMI). Data were analyzed thought the narmality test Shapiro-Wilk, followed by the Wilcoxon test. The present paper was approved by the Ethics Committee at UNIMEP, under the protocol 89/2004.
RESULTS: The results showed a significant pain relief (p<0,05), after the application of the TENS from the first to the fifth treatment. It was observed that in the applications 6, 7, 8, and 9 there was no significant difference. In the electromyographic evaluation, it was verified that, in the rest position, the individuals presented a significant increase (p<0,05) of the EMG activity of the right temporary muscle, after TENS application. In the other appraised muscles, no statistical significant differences were observed, after the treatment. In VCMI it was observed that, after TENS application, there was a decrease of the EMG activity of all the muscles and just in the right temporary muscle, there was a significant decrease (p<0,05).
CONCLUSIONS: It is believed that five TENS applications are enough to control pain; while a sole application is capable of reducing the pain significantly. It is also believed that the treatment with TENS is not enough to re-establish the electromyographic activity of the masticatory muscles in the rest position and of VCMI in TMD patients.

T12.P14
QUALITY OF REPORTING ELECTROMYOGRAPHY IN MASTICATORY MUSCLES - A SYSTEMATIC REVIEW

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AIMS: The objective of this study was to evaluate the quality of reporting electromyography in studies evaluating the masticatory muscles (masseter, temporialis, and pterigoids).
METHODS: A search of Medline, Pubmed, Embase, Web of Sciences, Scopus, and Cochrane Library databases was conducted in all languages with the help of a Health Sciences librarian. Key words used in the search were: electromyography, masticatory muscles, and their specific truncations according to each database. Abstracts were selected based on the criteria of using surface electromyography in masticatory muscles. Abstracts which fulfill the initial selection criteria were selected by consensus. The original articles were retrieved and evaluated to ensure they met the final inclusion criteria. An adapted methodological checklist published by the International Society of electromyography and Kinesiology (ISEK) was used to evaluate the quality of reporting electromyography in the selected articles.
RESULTS: A total of 154 abstracts were found through databases search. Finally, 41 studies were analyzed. The most commonly informed items concerning the electrodes were: electrode location (61%), electrode material (41%) and electrode geometry (41%). Regarding detection and amplification, 51% and 29% of the studies informed the type of amplification and the gain used respectively. Low high pass filters and cutt off frequences were informed in 61% of the analyzed articles. In reporting of EMG processing, 44% of the studies reported rectification and 27% reported the root mean square time period over which the average of EMG was calculated. Sampling rate into the computer was reported by 73%, and number of bites and model of A/D card used to sample data into the computer was informed by 24% of the studies. Concerning normalization, 32% of the studies reported method used for normalization procedure.
CONCLUSIONS: Based on the results obtained by this study, quality of reporting electromyography in studies evaluating masticatory muscles was poor. Most of the items proposed by the ISEK were not reported. Electrode material, electrode geometry, preparation of the skin, specific characteristics of the detection and amplification such as input impedance, common mode rejection ratio, signal to noise ratio, type of amplification, and gain used, were poorly informed. In addition, specifications about normalization procedure when applicable, and data about electromyographic processing were not described. Based on this results, the findings from the studies included in this systematic review should be interpreted with caution. Appropriate report and use of EMG technique in studies evaluating masticatory muscles is necessary in order to provide more accurate results and conclusions.

T12.P15
ELECTROMYOGRAPHIC ACTIVITY OF THE MASTICATORY AND CERVICAL MUSCLES DURING RESISTED JAW OPENING MOVEMENT

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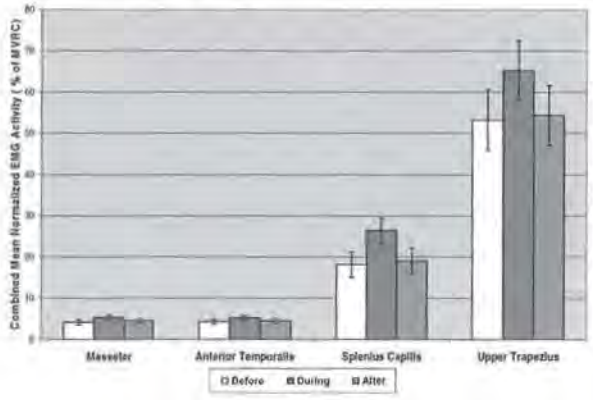
AIMS: The aim of this study was to evaluate the electromyographic activity of the masticatory muscles and cervical muscles during resisted jaw opening movement using the agonist contract-antagonist relax technique.
METHODS: This study was a quasi-experimental repeated measures design. A convenience sample of 30 students who attend the University of Alberta was recruited for this study consisting of 17 females and 13 males (using α= 0.05, β= 0.20, power= 80%, and effect size=0.25). Surface electrodes were placed on the superficial masseter and anterior temporalis muscles bilaterally as described in the protocol of Ferrario et al., and on the right and left upper trapezius and splenius capitis muscles bilaterally as described by Keshner, Campbell, Katz, & Peterson. The muscular activity was evaluated using an EMG 100C system, using a bipolar configuration (BIOPAC Systems Inc®). The data acquisition was sampled at 2000 Hz, and was amplified to 1000 (kilogain). The EMG activity was analyzed using *AcqKnowledge®* software from BIOPAC systems, Inc. which allowed filtering of the signals obtained and calculating the root mean square (RMS). As a normalization reference, EMG data were collected during maximal voluntary referential contraction (MVRC). This procedure was performed for every muscle being analyzed. A submaximal resistance to the jaw opening movement using the agonist contract-antagonist relax technique was applied to the subjects in order to determine the effect of this technique on the activity of the masticatory and cervical muscles. Electromyography activity of the superficial masseter, anterior temporalis, upper trapezius and splenius capitis was registered before, during and after the application of the submaximal resistance to the jaw opening movement. A two way ANOVA repeated measures analysis was used to analyze data. The level of significance was at a=0.05.
RESULTS: A submaximal resistance to the jaw opening movement using the agonist contract-antagonist relax technique increased significantly the EMG activity of both the masticatory muscles and the cervical muscles during and after the application of the technique ($p<0.05$).
CONCLUSIONS: Based on the results obtained from this study, the behavior of all muscles analyzed (masseter, anterior temporalis, splenius capitis and upper trapezius) was similar in that all muscles increased their activity when the resistance to the jaw opening movement was applied. Complex muscular interactions of supra and infrahyoid muscles (jaw openers), masticatory muscles, and cervical muscles exist to stabilize the craniomandibular system during resisted jaw opening.



Combined mean normalized EMG activity for masticatory muscles and cervical muscles before, during and after the AC technique.

T12.P16
EFFECT OF TREATMENT OF DENTOFACIAL DEFORMITIES ON THE ELECTROMYOGRAPHIC ACTIVITY OF MASTICATORY MUSCLES

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AIMS: The objective of the present study was to determine the influence of interdisciplinary treatment in cases of class III dentofacial deformities regarding the electromyographic activity of the temporal and masseter muscles.
METHODS: The study was conducted on 15 patients with class III dentofacial deformities who were submitted to orthodontic, oromyofunctional and surgical treatment and assigned to groups Patients 1 (before surgery) and Patients 2 (six to nine months after surgery). Fifteen individuals with no alterations in facial morphology or dental occlusion and without signs or symptoms of temporomandibular joint dysfunction were used as controls. The temporal and masseter muscles were submitted to electromyography bilaterally in the situations of mastication and mastication plus biting, with analysis of root mean square.
RESULTS: For all muscles tested, there was a difference between Control Group, Patients 1 and Patients 2; Control Group was higher than Patients 2 and Patients 2 higher than Patients 1 in all situations assessed.
CONCLUSIONS: We conclude that there was an increase in electromyographic activity in the temporal and masseter muscles after surgical correction of the dentofacial deformity accompanied by interdisciplinary treatment, although the values were still lower than those obtained for Control Group.

Electromyography evaluation equipment.

T12.P17
ELECTROMYOGRAPHIC EVALUATION OF MUSCLES IN EDENTULOUS PATIENTS USING COMPLETE DENTURES WITH SLIDING PLATES

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AIMS: This work was performed with the purpose of investigating the EMG activity of the anterior temporalis and masseter muscles in edentulous individuals with Temporomandibular Disorder (TMD), before and after using sliding plates on complete dentures, in mandibular rest position. The patients were edentulous at least ten years.
METHODS: The EMG recordings were made before the insertion of the dentures (0 month) and also after using the sliding plates at the 4th month, 9th month, and 12th month, using a computerized electromyograph. The electromyographic (EMG) evaluations of the muscles were performed under the following clinical conditions: Rest Position with Dentures - (R1), Rest Position without Dentures - (R2), Rest Position with Dentures Post-mastication - (R3), Rest Position without Dentures Post-mastication - (R4).

RESULTS: The results were submitted to variance analysis and lead to the following conclusions:
CONCLUSIONS: 1) The lowest EMG value was found in R3, and the highest EMG value in R2, showing a statistically significant difference ($p<0.05$); 2) the EMG activity of the Temporalis muscle was significantly higher than that of the Masseter muscle ($p<0.01$); 3) there were no significant differences between sides (left and right) of muscles and periods of evaluation.

T12.P18
ELETROMYOGRAPHIC ACTIVITY OF THE ORBICULAR MUSCLE OF THE MOUTH STUTTERERS AND FLUENT SPEAKERS

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AIMS: To compare individuals with stuttering complaint and without speech complaint concerning the electromyographic activity of the orbicular muscles of the mouth, upper and lower fascicles.
METHODS: 10 individuals with stuttering and 10 without stuttering (control group) took part in this study; they were paired by gender and age, between 10 and 18 years old. Groups were defined by the speech samples analysis of the ABFW - Language Test. In order to analyze the muscle activity, a K6-I EMG Light Channel Surface Electromyography (Myo-tronics Co. Seattle, WA, EUA) of eight channels was used. Double disposable electrodes of silver chloride surface were used (Duotrodes, Myo-tronics Co., Seattle, WA), with a conductor gel (Myogel-myo-tronics Co., Seatlle, WA). The electrodes were positioned in the orbicular muscles, following the muscle fibers orientation A reference electrode (ground) was positioned near the back of the patients neck. The patient remained sited in a comfortable chair, with the head positioned straight according to Frankfourt plan. The necessary instructions were previously given. The clinical conditions investigated were: maximum voluntary dental clench; one word and two sentences utterance; labial compression; lateralization of the united lips to the right and to the left; labial protrusion; labial retraction; cereal bar chewing; resting before and after the exercises. Eletromyographic data were normalized by maximum voluntary contraction during dental clenching. The comparison between the groups was performed with the t-Student test for unpaired data (Statistics Software).
RESULTS: In all clinical conditions, the activity of the muscle orbicular of the mouth, upper fascicle, was higher in the control group than in the group with stuttering, with a significant statistical difference in the following conditions: sentence utterance with a dominance of the Brazilian Portuguese language plosive phonemes, lips lateralization to the right and to the left ($p<0,05$), cereal bar chewing, rest before and after the exercises ($p<0,01$). There was no significant statistical difference between the groups regarding the muscle orbicular of the mouth, lower fascicle ($p>0,05$).
CONCLUSION: According to the results, the orbicular of the mouth, upper fascicle, muscle activity of the group with stuttering was significantly lower than the control group in the majority of the clinical conditions analyzed, which may suggest that the tension observed during the stuttering spontaneous speech may be a compensatory process to an abnormal neuromuscular physiology.

T12.P19
THE USE OF EIGHT-POINT BINDING AS A PHYSIOTHERAPEUTIC RESOURCE FOR THE MUSCULAR DORSIFLEXORES'S RECRUITMENT IN GAIT

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AIMS: The objective of this study is to verify the effects of the use of eight-point binding in the dorsiflexion of neurological patients in walking.
METHODS: Recruited were neurological patients in physiotherapeutic service in the Clinic of Physiotherapy of UniFMU. For the accomplishment of this work, a catwalk of 10m of length and a chronometer was used. It was requested the execution of comfortable and accelerated walking during the marked 10 m, with the time being measured. Soon afterwards, the surface electromyography evaluation of the anterior tibial muscle was carried out for one minute using an ergometric treadmill with a velocity of 0.5 km/h. The evaluation using the same initial parameters (velocity and electromyographic activity) was later accomplished with the use of binding. For analysis of the data, the average of the medium values for comfortable walk, accelerated walk, maximum peak and average, with and without the use of eight-point binding was used.
RESULTS: Results were obtained that the use of eight-point binding promoted the increase of comfortable and accelerated velocity in patients with dorsiflexion difficulty. The electromyographic activity of the anterior tibial muscle was greater with the use of eight-point binding, which guarantees the dynamics of a more appropriate operation of this muscle.
CONCLUSION: The findings of this study allow a research line to be established on the subject, selecting a larger and more homogeneous sample to guarantee internal and external validity to the data.

T12.P20
COMPARATIVE ANALYSES OF THE PAIN AND THE EMG ACTIVITY OF TRAPEZIUM AFTER TENS AND POSITIONAL RELEASE THERAPY

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INTRODUCTION: The Positional Release Therapy method is a therapeutic method that has been proving through clinical practice great results when treating vary algic situations. It's an indirect procedure that uses body positioning and sensitive points to identify the injury and to monitor the therapeutic intervention, and an indirect approach when referring to tissular resistance, having a solid physiologic basis.
The trapezius muscle is very demanded in some functional daily activities and its use is sometimes inadequate to the activity accomplishment, altering the normal functional cinematic and leading to pain. The Transcutaneous Electrical Nerve Stimulation (TENS) is one of the oldest and more effective modality used in physiotherapy in order to relieve the pain. Thus, the main goal of this paper was to analyze the trapezius muscle recruitment before and after a PRT and TENS' application through the Surface Electromyography that registers the muscle electrical activity responding to the physiological contraction.
It was also analyzed the pain level of each person through the pain scale.
METHODOLOGY: In order to fulfill this research, 40 women between the age of 20 and 40 years old who suffered from pain in their trapezius (descendent fibers) were randomized and divided in 3 groups without the algic complainings. The first group received a PRT application, the second one a 40 minute TENS application and the third one was a control group, that received series of 30 seconds sequential stretching activities. The 3 groups were evaluated by the sEMG and the pain scale before and after the experience. As a means to capture the recruitment of the trapezius muscle (descendent muscles), circular electrodes of silver cloretium of the Medtrace brand and an Electromyographic model 4000 of 4 channels of the Miotec brand were used and placed on the surface of the motor region which was previously cleaned with cotton soaked with alcohol 70%.
RESULTS: Analyzing each group separately before and after each technique through the sEMG and the algometry, by using Wilcoxon test with 95% of statistics' reliability, the first group had a statistically significant medium difference in both analysis.

where it was noticed that after the technique application, there was a decrease of the muscular recruitment of the trapezius and also a decrease of the pain through the algometry.
Yet the second and the third groups did not present any statistics' difference. Comparing the three groups among themselves, through the Kruskal-Wallis and the Mann-Whitney tests, also with 95% of reliability, it was observed that group 1 is always different from the others, which are on the other side similar to each other by showing no significant difference in the results.
CONCLUSION: These data show us that the application of the PRT procedure made the muscular fibers which are descendent from the trapezius better aligned and equilibrated. Consequently, it presented us a diminution of the pain in this musculature, what could not be observed with other followed procedures, like TENS and sequential stretching, what proved us that the first method was more efficient in comparison to the other 2 methods.

T12.P21
THE DIFFERENCE OF ALIGNMENT OF LUMBAR VERTEBRAE AND LUMBAR RANGE OF MOTION IN FOUR POSTURES

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AIMS: There is a slight lumbar lordosis in normal curve spine in standing. The slight lumbar lordosis is very important to prevent and manage low back pain. Pelvic tilting movement is used in different posture to control lumbar-pelvic alignment. The alignment of lumbar vertebrae (ALV) changes in lumbar range of motion (L-ROM) between maximal lumbar extension position and maximal lumbar flexion position due to pelvic tilting movement in sagittal plane. Extent of L-ROM in extension and flexion scale was affected by body posture. However, state between E-ROM and ALV in standing spinal curvature is not clear. The purpose of this study is to clarify the state of extent of L-ROM in four postures and ALV in standing, and compare the ALV at comfortable resting position in four postures.
METHODS: Twelve healthy male subjects with a mean age of 21.1 years (range=19-24) participated voluntary in this study. ALV was measured using two electrical inclinometers (dualer IQTM: JTech Medical Industries. USA) placed over T12 vertebra spinous process and sacral 2nd vertebra. L-ROM were calculated by subtracting ALV at maximally anterioly pelvic tilt position from ALV at maximally posterioly pelvic tilt position.
Data for each subject were collected at comfortable resting position, and at maximally anterioly and posterioly tilting of pelvis in four postures; 1) standing in knee 0° flexion, 2) standing in knee 30° flexion, 3) sitting position, 4) four point kneeling position (FPK).
RESULTS: ALV at comfortable resting position (mean±SD) were 1) -27.3±5.4°, 2) -21.3±4.3°, 3) 6.2±11.2°, 4) 1.4±5.9° in four postures respectively. ALV at maximally anterioly pelvic tilt position were 1) -36.8±6.8°, 2) -36.1±7.0°, 3) -19.8±10.9°, 4) -31.8±7.4°. ALV at maximally posterioly pelvic tilt position were 1) -11.6±11.8°, 2) -5.3±11.3°, 3) 22.2±8.1°, 4) 24.0±7.1°. L-ROMS were 1) 25.3±9.3°, 2) 30.8±8.6°, 3) 42.0±11.8°, 4) 55.8±9.9°. ALV in comfortable resting position, at maximally anterioly pelvic tilt position, at maximally posterioly pelvic tilt position and L-ROMS were significantly different between four postures (ANOVA $p<0.01$). ALV at comfortable resting position in sitting and FPK were in more flexed position than in standing. Extent of ALV at comfortable resting position in standing did not overlie in extent of ALV in sitting, and similar to the ALV at maximally anterioly pelvic tilt position in FPK.
CONCLUSIONS: The results showed the ALV and L-ROM were affected by posture. It implied the necessity the consideration of the effects of posture for pelvic tilting movement to control ALV.

T12.P22
EVALUATION OF THE REDUCTION OF PAIN IN DESCENDING FIBERS OF THE TRAPEZIUM, AFTER THE APPLICATION OF PRT (POSITIONAL RELEASE THERAPY) TECHNIQUE

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INTRODUCTION: Positional Release Therapy is an indirect technique, in other words, the application of force is used far from the barrier of resistance, that is, in the direction of greater ease. It is a method of total evaluation of the body and of treatment using sensitive points (SPs) in a position in that the state of tension of the muscular fibers is reduced to the maximum, to solve the associated dysfunction. The sensitive points are located and palpated, soon after a comfort position is sought, which this comfort produces the ideal relaxation of the involved fibers. The results shown of using Positional Release Therapy, occur with an increase of muscular force and a decrease of muscular and fascial tension, pain and articular hypomobility.
AIMS: The objective of the present study was to verify the reduction of pain, through an analogical visual scale, of descending fibers of the trapezium after the use of the PRT (Positional Release Therapy) technique.
MATERIAL AND METHOD: SUBJECTS: The collection of data was accomplished with 80 tennis playing students at the Academia Pro Sport S/C Ltda, masculine, ages between 18 to 30 years, the same being , students of more than three months and presenting pain above 5 in a visual analogical scale after the palpation of the tender point of the descending fibers of the trapezium.
PROCEDURE: All of the samples were divided into two groups, a treatment group and a control group, therefore, containing 40 individuals in each. For the individuals of the treatment group (PRT) the correct form of the technique was applied, while for the samples of the control group, an incorrect form was applied.
ANALYSIS OF THE DATA: A level of significance of 0.05 was defined for this work. All of the confidence intervals built throughout the work were built with 95% of statistical confidence.
RESULTS and DISCUSSION: After having made the entire

Before vs. After	Control		PRT	
	Before	After	Before	After
Average	6.65	6.13	6.68	2.58
Median	6.5	6	7	2
Std. Deviation	1.19	1.26	1.23	1.53
Minimum	5	3	5	0
Maxium	9	8	9	6
Size	40	40	40	40
Inferior Limit	6.28	5.73	6.29	2.10
Superior Limit	7.02	6.52	7.06	3.05
p-value	0.059#		<0.001*	

Illustration 1: Comparison of the evaluations before versus after in each of the groups.

Groups	Before		After	
	Control	PRT	Control	PRT
Average	6.65	6.68	6.13	2.58
Median	6.5	7	6	2
Std. Deviation	1.19	1.23	1.26	1.53
Minimum	5	5	3	0
Maximum	9	9	8	6
Size	40	40	40	40
Inferior Limit	6.28	6.29	5.73	2.10
Superior Limit	7.02	7.06	6.52	3.05
p-value	0.927		<0.001*	

Illustration 2: Comparison of the groups among themselves

collection of data and statistical analysis, it was established that averages for both of the groups after the evaluation were smaller than the average before, but only in the group of PRT, can it be said that a statistically significant difference in the average exists (illustration 1). Although there is a reduction of the average in the control group, we cannot say it to be statistically significant. However, as the p-value is very close to the acceptable limit, we can say (if necessary) that a tendency exists to the difference. It is only in later evaluation that a difference exists between the groups control and PRT, where the group PRT possesses a lesser average (illustration 2). It was clear, therefore, that PRT performed in a correct way has demonstrated effectiveness in the reduction of pain and of muscular tension exercised in the descending fibers of the trapezium.

T12.P23
INFLUENCE OF THE APPLICATION OF TENS ON THE ELECTROMYOGRAPHIC ACTIVITY OF CERVICAL MUSCLES IN DYSPHONIC PATIENTS

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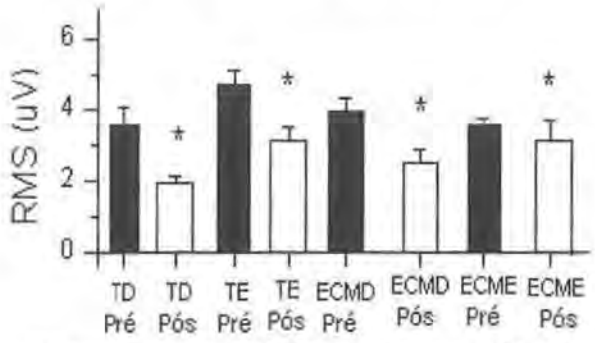
AIMS: To analyze the effect of TENS on the electromyographic activity of the superior trapezium muscles and sternocleidomastoid muscles of dysphonic women.
METHODS: This study comprised 10 dysphonic volunteers (33.6±8.0 years of age), who presented with bilateral nodules or thickened mucosa and fissure during phonation, verified by means of laryngoscopy and otorhinolaryngologic exam. For the electromyography an electromyograph (EMG1000 by LYNX®) and active surface electrodes were used, placed on the thickest part of the superior trapezium and sternocleidomastoid muscles. The exam was performed during the pronunciation of spontaneous speech for 7 seconds and was repeated 3 times. The application of TENS was conducted with a Dualpex 961 appliance (Quark Produtos Médicos®), following a low frequency protocol (10 Hz and 200 µs), with intensity at the motor threshold, during 10 sessions of 30-minutes each on alternate days. The electromyography was collected before and after the period of TENS intervention. The signals were analyzed by the square root of the mean (SRM), in a specific implemented routine of the software Matlab® 6.5.1. The data were analyzed by the Shapiro-Wilk normality test (JMP®) followed by the Wilcoxon test (Statgraphics Plus® 1.4). This present study was approved by the UNIMEP Ethical Committee under Protocol 89/2003.
RESULTS: In the electromyographic assessment of the right trapezium muscles (TD), left trapezium muscles (TE) and right sternocleidomastoid (ECMD) and left sternocleidomastoid (ECME), a significant bilateral reduction of the SRM could be verified after the period of TENS intervention (Figure 1).



Electromyographic activity of the trapezium muscles (T) and sternocleidomastoid (ECM) right (D) and Left (E), pre and post TENS intervention period. n=10. p, 0.05 in relation to the respective pre.*

CONCLUSIONS: The period of 10 sessions of low frequency TENS application at the motor threshold may be considered to be effective for diminishing the electromyographic activity of the trapezium and sternocleidomastoid muscles in dysphonic women.

T12.P24
EFFECTS OF AMBULATORY AIDS ON POSTURAL STABILITY

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AIMS: Canes and crutches are used as ambulatory aids in order to enhance postural stability and walking ability. There have been a number of studies carried out on canes and crutches, but the majority of them focus attention on the balance mechanism of the body and muscle activity in the lower limbs. The purpose of this study was to examine the participants' postural stability by comparing the sway and the muscle activities of the upper limb during the use of the ambulatory aids.
METHODS: After obtained informed consent, eight healthy men participated in this present stady. The three types of ambulatory aids used in this study were the T-shaped cane (T-cane), Quad cane (Q-cane) and Lofstrand crutch (L-crutch). The left lower limb of the participant was chosen as the affected leg, and the right lower limb as the non-affected leg. The three ambulatory aids were held by the contralateral hand to the affected leg. Each participant was required to stand on the affected leg for five seconds with 20% of their body weight (20% BW) applied through the ambulatory aids. The sway of the upper limb was measured by a 3-dimensional motion capture system (VICON512). The intended interval for the analysis was a three-second period out of five seconds where 20% BW was constant during the experiment. A calculation was made for the mean and standard deviations for the sway values of the movement of the upper limb markers and the total path length of the movement. They were both measured in mm in the mediolateral (X-direction) and anteroposterior (Y-direction) on a horizontal plane. These values were compared among the three types of ambulatory aids. Then, the EMG activities of the upper limb were detected from biceps brachii, triceps brachii, deltoid (anterior medial posterior), pectoralis major and latissimus dorsi with bipolar surface electrodes. The EMG signals were digitized at a sampling rate of 1kHz, filtered using a bandwidth ranging from 10 Hz to 500 Hz and integrated (IEMG).
RESULTS: The mean sway of T-cane for the shoulder, elbow and wrist joints were significantly larger than L-crutch ($P<.01$), and larger than Q-cane ($p<.01$) in the shoulder and wrist joints. The mean sway for Q-cane showed significantly larger than in relation to L-crutch ($P<.05$) in the shoulder and elbow joints. The normalized IEMG value of biceps brachii, triceps brachii, deltoid (medial posterior), and latissimus dorsi while standing were significantly larger in T-cane and Q-cane than L-crutch ($P<.05$). The normalized IEMG value of pectoralis major was significantly larger in Q-cane than L-crutch ($P<.01$). The normalized IEMG values of deltoid (anterior) showed no significant difference among three types of ambulatory aids ($P>.3$).
CONCLUSIONS: A larger upper limb sway was observed when the participant stood on one leg with 20%BW applied to the T-cane or Q-cane. This finding suggested that the T-cane and Q-cane were more effective in improving the participant's balance capability rather than reducing the load on the lower limb. However, with the L-crutch, the upper limb sway was found to be the smallest even with 20%BW. This finding suggested that the L-crutch was the most effective in reducing the load on the lower limb and provided better postural stability by reducing body sway.

T12.P25
ANALYSIS OF POSTURAL REACTION OF SITTING BALANCE USING BALANCE BOARD

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AIMS: Hemiplegic patients describes some difficulty in smooth weight shifting either to the right or left direction caused by reduction of the trunk function and postural reaction in his/her affected side. It is useful to analyze sitting balance on laterally unstable board(balance board) in the treatment of hemiplegic patients. The aim of this study is to clarify the segmental body strategy found in a group of healthy persons and that of hemiplegic patients reacting on the sitting subject on the tilting balance board.
SUBJECTS: Ten healthy persons (mean age 69.4 years) and six stroke patients (4 left hemiplegia and 2 right hemiplegia; mean age 59.7 years) were subjected to the study. In the patient group, it elapsed about 7 weeks from onset and the severity of motor paresis was moderate enough to keep a sitting position. All subjects were obtained written informed consent.
METHODS: Subjects sat sideways on the balance board with distal 25% of thigh length coming out from the end of sitting surface and the following tasks were performed withoutleg support but with eyes open. Subject reacted on the balance board which was tilted in 7 degrees. The measurement of tilt were done first toward left in healthy persons, and toward unaffected side in hemiplegic patients. The order of the other three measurements were as follows: right, right, and left in healthy persons and affected side, affected side, and unaffected side in hemiplegic patients. A digital video camera was set backward, and 8 markers were attached to the head, left and right acromions, vertebral column (C7-T7-L4) and left and right posterior superior iliac spine of the subjects. Positions at 2-dimentional coordinates were calculated with motion analysis software (DKH, Frame-DIAS2). A statistical test was carried out with one way ANOVA.
RESULTS: (1) In comparing angle change of unaffected and affected side tilting with healthy persons, the deviation of both shoulders angle was 1.4 degrees in healthy persons that tend to indicate higher value in hemiplegic patients ($p=0.07$). Hemiplegic patients showed that both shoulders moved in the same direction as tilting. On the other hand, the deviation of upper trunk angle was 4.6 degrees in unaffected side tilting, and 3.8 degrees in affected side tilting tend to be higher than in healthy persons ($p=0.07$). (2) In comparing an angle with segmental body, the movement of pelvis was mainly seen in healthy persons, and the movement of upper trunk was mainly seen in hemiplegic patients.
DISCUSSION and CONCLUSIONS: While the subject reacted on the sitting subject on the tilting balance board, healthy persons mainly used movement of pelvis. On the contrary, hemiplegic patients mainly used upper trunk movement. It was thought that this was caused by deficiency of the pelvis movement in hemiplegic patients. This coincided with clinical observation and suggested the usefulness of methodology of this study.

T12.P26
DEVELOPMENT OF THE COMPACT MRI ENABLED FOOT IMAGING IN STANDING POSTURE

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AIMS: Foot arch composed of the tarsal, the metatarsal, the plantar aponeurosis, and a foot muscle has the function to absorb and to ease the impact that joins from ground. There are many studies of foot arch from inside information with X-rays, CT or MRI, and from outside information with foot print, arch high rate or 3-dimensions motion analyzer. However, in patients with deformation, osteoarthritis or ligament injury, there is no anatomical or kinematic information by 3-dimensional detailed imaging of ankle joint, knee joint or lower extremity in standing posture
We developed the compact MRI device which we could measure in standing position which was not carried out worldwide.
EQUIPMENT: The development device was the specification of 0.22T type magnetic circuit (Made of NEOMAX; two U type pillar), it is resonance frequency; 9,339MHz, size; about 80 cm legislations, weight; about 540 kg, a gap; 170 mm, uniformity coefficient of static magnetic field; 53ppm@120mmDSV, incline magnetic field efficiency (mT/m/A); GX=GY=GZ=1.3, 5 G magnetic field radius; about 70cm from center, and power supplies; AC100V. The RF coil was designed to endure the load in the upright position, and according to change the direction of RF coil, it could take a knee joint imaging. To enable the movement compactly, the measurement part was shielded with the special cloth coated by silver.
EVALUATION: We evaluated about reproduction characteristics and a distortion of imaging with 7 cm plastic balls which satisfied baby oil. In addition, we did photography repeatedly about 2 male and 2 female feet, and evaluated it about reproduction characteristics and a distortion. We explained the subjects to a purpose of a study, a method, danger of an experiment beforehand, and got the agreements of all subjects.
RESULTS: It was recognized to some warped difference in the X, Y, and Z direction, but comparatively stable imaging was taken, and there was a little warp if it was a range of about 10 cm balls of the magnetic field center.
DISCUSSION: It is unknown in the ability of an internal structure to be caught correctly using external information. And it is difficult to distinguish between cartilage and soft tissue, and to clear the outline of a bone structure from overlapped plural bones by X-ray photography. Moreover, a measurement in standing posture is difficult in conventional CT and MRI. Therefore, the almost research on the functional characteristic of the foot arch is the physical-properties examination which mainly used a cadaver.
As this developed MRI devise is designed to be able to take a image in standing position, the measurements of the 3-D form and the weight change in the knee joint, the ankle joint, and lower extremity are enabled with it.

T12.P27
INFLUENCES OF VISUAL VERTICALITY ON POSTURAL CONTROL OF HEMIPLEGIC PATIENTS

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INTRODUCTION: Spatial orientation of subjective visual vertical (equals visual verticality, SVV) is an important factor for the postural control. Disorders of SVV are observed in patients with hemiplegia due to cerebral vascular accident and such patients will be improved sitting balance by manipulating the SVV.
AIMS: The purpose of this study is to measure the SVV and body tilt angle for oblique visual target, and to clarify the influences of visual verticality on sitting balance in hemiplegic patients.
SUBJECT: Fifteen patients due to cerebral vascular accident were included in the study. Patients divided into two groups, 7 right hemiplegic group (RH, mean age 47.3 years old), and 8 left hemiplegic group (LH, mean age 60.7 years old). All subjects were informed of purport of the study and the consents were obtained by writing.
METHOD: Subjects sat sideways on a flat table and the following tasks were performed with no legs support in the dark room. A luminous rod of 40 centimeter length generating by personal computer was projected on the screen at frontal plane and at 2 meter distance from subjects. Measurement of SVV was done

with this system, subjects were asked to orient the rotating rod at 5 degrees/sec speed until subjective vertical was obtained (Task 1). After Task1, subjects were asked to adjust their body exactly along to the tilting and fixed rod by 15 degrees (oblique target) on the screen (Task 2). Number of trials was 8 in each task. Simultaneously, a digital video camera was set backward, and 2 markers were attached to the C7 and L4 vertebral column of subjects. Tranchial angle at 2-dimentional coordinates were calculated with motion analysis software. In analysis of mean value (constant error), the clockwise direction was plus sign and the counter-clockwise was minus. Standard deviation of obtained data was as the index of variability of judgments and performances (absolute error). A statistical test was carried out with Student t-test.

RESULTS: In the task 1, there was no significant difference as to the mean value of SVV in both RH and LH patients groups. However LH group showed significant larger value of SD (2.3) than that of RH group (1.1). The body tilt adjustment angle to oblique target in the task 2 , LH group indicated -9 degrees of the tranchial angle for left tilted target and RH group demonstrated 7.6 degrees for right tilted target. In task of body tilt for affected side, LH group showed larger SD value than RH group.

DISCUSSION and CONCLUSION: The difficulty of adjusting the body to the paretic side was confirmed in both groups in this study, suggesting consistency with clinical observation. Especially in LH group patients, it suggests that the variability of visual verticality affect strongly on keeping balance of postural control.

T12.P28
ARM, NECK AND TRUNK COORDINATION DURING EATING ACTION IN PATIENTS WITH RIGHT HEMIPLEGIA

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AIMS: The purpose of this study is to investigate the coordianation between neck, trunk and arm during the eating action and to compare characteristics of movements of patients with right hemiplegia with those of non-disabled people.

METHODS: Twenty seven patients with right hemiplegia (nine women and eighteen men) and fifteen non-disabled people (five women and ten men) were required to eat yoghurt in a bowl with their left hands. All subjects were right-handed. The research ethics committee approved the project. Informed consent was obtained from all subjects. The total task encompassed graspint the spoon and (1) reaching with the spoon to hte bowl, (2) filling the spoon with the yoghurt, (3) transporting the filled spoon to the mouth and emptying it. Aside from instructing subjects 'to eat as you would normally do', no additional constraints were imposed upon them. Using four cameras, we recorded the position of light reflecting markers attached to the subjects' bodies. These kinematic landmarks were used to define the dependent variables. We calculated the total movement duration and the movement duration of each phase. And we computed the range of motion of nine joint angles (trunk flexion and rotation, neck flexion, shoulder flexion and abduction, elbow flexion, forearm supination and wrist extension), the peak velocity and the percentage of time to peak velocity with a three-dimensional video-based motion analysis. Movement duration and kinematic variables were analyzed with Wilcoxon signed rank test between patients and non-disabled subjects. Regression analysis was used to determine correlations between temporal events of these angles.

RESULTS: The total movement duration and the the movemnet duration of second phase of patients were longer than non-disabled people($P<0.05$). There was statistically no diffrence about range of motion of joint angles between patients and non-disabled poeple except for forarm rotation wrist movement. Correlations coefficients among time of peak velocity of these angles were different between patient and non-disabled people.

CONCLUSIONS: Previous researcher indicated a problem of coordinating the arm and trunk of patients with rigth hemiplegia. Our result also suggests that patients with right hemiplegia might have difficulty coordinating the mouth and the hand because of impaired control of movement involving complex co-ordination between arm neck and trunk. Eating is one self-care task many patients can do independently in the recovery stage, and many helth care staffs approach this task. However, even though patients often can eat independently, they sometimes have difficulties. We indicates that it might be helpful for therapists to address neck and trunk mobility to improve eating skills.

T12.P29
EFFECT OF FACILITATION OF BALANCE ABILITY USING BALANCE BOARD IN HEMIPLEGIC PATIENTS AFTER STROKE

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AIMS: It is important that patients with hemiplegia caused by a stroke can stand up independently so that they can practice walking. The purpose of this study was to examine the effects of an electric balance board used to facilitate sit-to-stand performance.

METHODS: SUBJECTS: The subjects were 8 patients with hemiplegia, 5 with left and 3 with right hemiplegia, caused by cortical or subcortical stroke less than 12 months before the study. Their mean age was 66 years. All subjects gave informed consent. PRE-TEST: Five trials of a sit-to-stand (STS) task was timed. After the STS task, the subjects in a sitting position performed 3 trials of a functional reach test (FRT-S) in which they extended forward to their limit their unaffected upper limb in the saggital plane. INTERVENTION: Subjects tried to keep sitting upright on an electrically powered board as it was tilted forward 10 times by 10 degrees and backward 10 times by 10 degrees. POST-TEST: After the intervention, the subjects performed the STS and FRT-S tasks again.

RESULTS: There was no difference between the performance of the STS before and after the intervention. In the FRT-S task, the subjects were able to reach further after than before the intervention regardless of the direction of tilt ($p<0.05$).

CONCLUSIONS: The forward tilt stimulus given by the balance board may facilitate an anterior shift of the center of gravity, and the backward tilt stimulus may facilitate a righting reaction and increased bending forward of the trunk. FRT-S can be used to clinically assess balance ability. The study suggests that the electrical balance board may be a useful method of improving trunk balance reactions of hemiplegic patients.

T12.P30
ELICITING MUSCULAR ACTIVITY IN SPINAL CORD INJURED PERSONS EXPOSED TO LEG VIBRATION

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AIMS: It is the aim of this study to show the activation of the muscle spindle reflex in motor complete spinal cord injured (SCI) persons while being exposed to leg vibration. An increased muscular activity is important in SCI, as it may help to prevent muscular atrophy, pressure sores and osteoporosis, thus reducing complications.

METHODS: Subjects are tested in sitting or lying position (different stretch of the lower limb muscles) with their feet on an adapted Galileo Home+vibration board. The amplitude of the vibration can be adapted depending on the feet's position. After positioning of the subject, feet are fixed to the board and vibration is started. During the vibration (with 10, 20, 30 Hz for 5 s each) EMG is recorded. All surface electrodes are equipped with an electronic pre-amplifier. From both legs the EMGs of Mm.

Quadriceps, Mm. Hamstrings, Mm. Gastrocnemius, Mm. Soleus and Mm. Tibialis anterior are recorded.
RESULTS: The raw EMG signals contain noise injected by electronic equipment as well as motion artefacts caused by the displacement of the skin on the muscle belly (fig 1a and 1c). From the raw signal the vibration frequencies and the environmental interferences are filtered out (fig 1b and 1d). The signals are presented in the time and in the frequency domain (auto power spectrum). Further analyses (not presented here) will be cross-correlations of all the involved muscles' EMGs and detection of patterns or templates known to originate from muscular activity.
CONCLUSIONS: By detecting the EMG in the composed signal we want to identify muscular activity in motor complete SCI subjects. This implies that leg vibration might be a useful intervention for people with SCI.

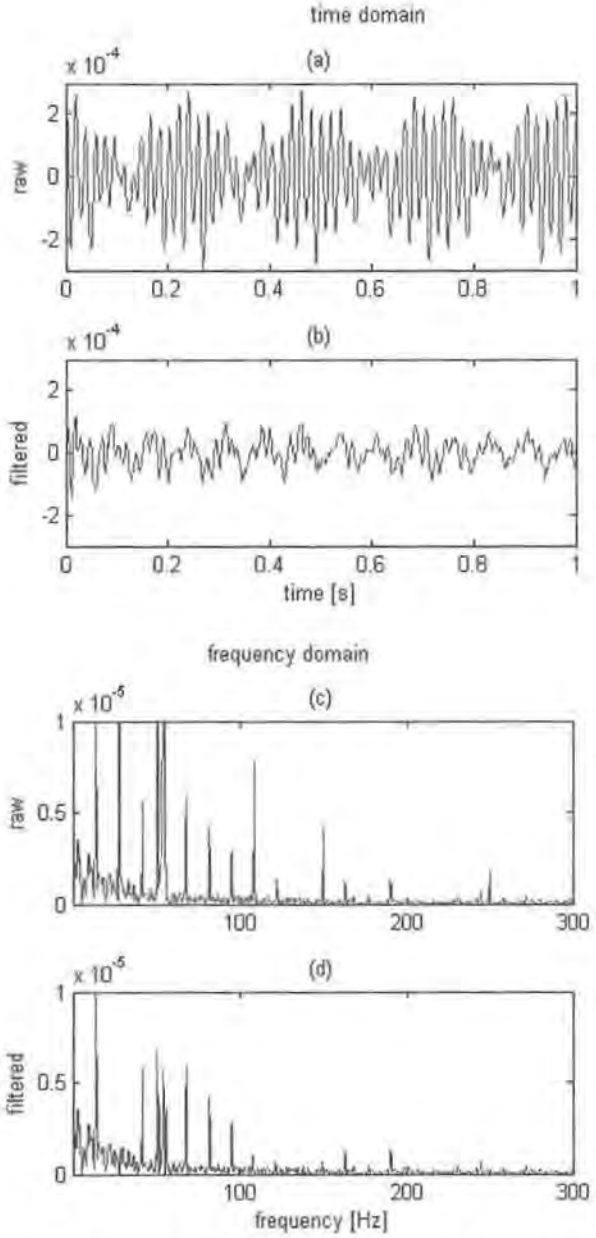

Fig 1. Example of EMG signal of Mm. Hamstrings exposed to 30 Hz vibration; raw (1a) and filtered (1b) signal in the time domain; raw (1c) and filtered (1d) signal in the frequency domain.

T12.P31
CORPORAL OSCILLATION DURING STATIC BIPED POSTURE IN CHILDREN WITH CEREBRAL PALSY

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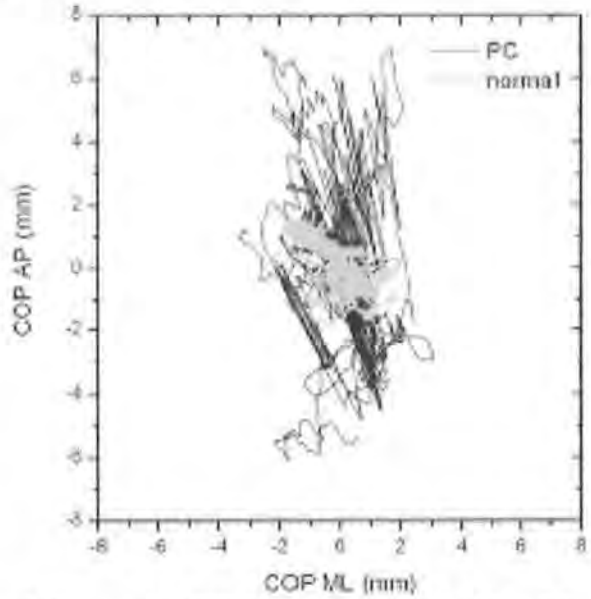
AIMS: Inability of posture and balance maintenance, muscular non coordination, difficulties of sensorial information organization and dysfunction of support during gait are problems that affect the independent functions. The oscillations occur due to the difficulty in keeping many corporal segments aligned in a small base of support - the feet. Besides the appearance of some evaluation scales of postural control, the clinical community is still dependant of objective, fast and accurate tools, to such important objective in physical rehabilitation. Hence, the objective of this previous study is to compare the anteroposterior and mediumlateral displacements and the speed of displacement of the COP of healthy children and compare them to children with cerebral palsy type spastic diparesy.
METHODS: This study had the participation of 10 healthy children (6 girls and 4 boys), between 5 and 10 (7,6±2,1) years old, and other 10 children, all diagnosed as CP type spastic diparesy, (5 girls and 5 boys), between 5 e 10 (7,3±1,8) years old. To collect the data, we used the antero-posterior (AP) e medium-lateral (ML) displacements of the COP. The parameters were compared by the variance analysis (ANOVA), and the post hoc test was Tukey's HSD. The level of significance adopted was $p<0,05$.
RESULTS: After the collect of data and statistical analysis, it was observed that the medium amplitude of the AP and ML displacements was higher in CP children, related to the healthy children: AP-$F_{(1,18)}$=1,66 (p=0,002), ML-$F_{(1,18)}$=3,36 (p=0,002). As the amplitude, the speed of the displacements was also different among the children. The speed of the displacements, AP and ML was higher in CP children - $F_{(1,36)}$= 0,009 (p=0,00). There were no differences between the speed of AP and ML displacements, neither in the healthy children, nor in CP ones - $F_{(1,36)}$= 0,00 (p=0,87).
CONCLUSIONS: The muscular misbalances, because of spasticity and motor incoordination, besides being retractions and several muscular weaknesses, may probably lead to temporal muscular contractions and specially wrong, and consequently, wider and faster oscillations. Hence, the sensorial deficit found in CP children is an important issue in the increase of the amplitude and speed of displacement of the COP.



Stabilogram of the COP of the healthy and Cerebral Palsy (PC) group.

T12.P32
PERONEOUS LONGUS MUSCLE REACTION TIME ANALYSIS DURING SUDDEN INVERSION TEST OF THE ANKLE THROUGH SURFACE ELECTROMYOGRAPHY: SYSTEMATIC REVIEW.

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AIMS: To review and to summarize studies dealing with peroneous longus reaction time evaluation through surface electromyography and to identify the influence by using paired limbs of the same or different subjects.
METHODS: The studies were identified by electronic research (with specific key-words) by two independent reviewers at the following databases: MEDLINE (1966-2004), EMBASE (1980-2004), LILACS (1982-2004), CINAHL (1982-2004) and specialized journals. Athlete and non-athlete subjects who had suffered or not ankle sprain inversion were included. These studies were divided into three groups: Group I - subjects with ankle sprain (paired by the opposite limb); Group II - subjects with or without injury (paired by limbs from different subjects) and Group III - subjects without injury, comparing the reaction time in other situations. The instrument used was a platform with two independent plates which dropped in inversion at frontal plane.
RESULTS: 17 full text articles (n=5, Group I; n=2, Group II; n=10, Group III) were selected. Comparing the peroneous longus reaction time (ms) between injured and not injured ankles, paired by the opposite limb, a statistically significant difference was found in favor of the injured ankles (weighted mean difference - WMD=0,31; IC 95% [0,02;0,60], p=0,04). The peroneous longus muscle reaction time paired by limbs from different subjects also presented a statistically significant difference, in favor of the injured ankles (WMD=3,46; IC 95% [2,44;4,48], p<0,001).
CONCLUSIONS: This study found a neuromuscular control deficit between injured and uninjured ankles, characterized by the difference on the peroneous longus muscle reaction time. The greater reaction time delay showed in the subjects with ankle injury (paired by limbs from different subjects) should be taken into consideration.

T12.P33
ESTABLISHMENT OF MOVEMENT INTENSITY AND THE OPTIMUM FREQUENCY OF MOVEMENT BY USING 1 REPETITION MAXIMUM

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AIMS: In the establishment of movement intensity by using 1 repetition maximum (1RM), the intensity levels 40-50% of 1RM, 50-60%, and 60% or higher have been believed to be effective for the improvement of coordination, endurance, and muscle strength, respectively. The optimum frequencies of movement at these intensity levels 90%, 80%, 70%, 60%, and 50% were 3, 8, 12, 20, and 40 times, respectively, at 2 seconds per one occasion of reciprocating motion (Kunz 1990). However, there have been no reports on frequency of movement in different muscles, articular movements or both males and females. In the present experiment the subjects were instructed to move several types of different muscles, and the optimum frequency of movement was investigated.
METHODS: The subjects were 22 healthy adults (11 males, 11 females). Their mean age was 27.2 years. The following 4 muscles were used for the experiment: The biceps brachii (BI) and the triceps brachii (TRI) of their dominant hand and the tibialis anterior (TA) and the rectus femoris (RF) on the side of kick. 1RM for each muscle was measured, and the subjects were instructed to repeat movements at movement speed of 2 seconds per one occasion of movement at movement intensity levels 90%, 80%, 70%, 60%, and 50%. The equipment used was Mobile Speed Pulley (LOJER) that facilitates alteration of loading [KG]. SPSS (ver. 12) was used for the statistical analysis.
RESULTS: The mean 1RM [KG] was 5.9 for BI, 10.4 for TRI, 10.5 for TA, and 6.8 for RF. In the quadratic regression formula in which the movement frequency was plotted along the Y axis and percent (%) of 1RM was plotted along the X axis, R^2 value was 0.68 for all the muscles, 0.84 for BI, 0.81 for TRI, 0.82 for TA, and 0.77 for RF. Thus, the value was significant in all the muscles. The movement frequencies measured by substituting the intensity levels 90%, 80%, 70%, 60%, and 50% for each quadratic formula were 5, 11, 17, 24, and 32 times for all muscles, 5, 13, 22, 34, and 49 times for BI, 6, 12, 17, 24, and 30 times for TRI, 5, 10, 15, 21, and 28 times for TA, and 4, 8, 12, 17, and 22 times for RF. There were significant differences in frequencies at 70%, 60%, and 50% between BI and TRI and at 80%, 70%, 60%, and 50% between TA and RF.
CONCLUSIONS: When comparing the frequencies of movement among the muscles of the upper and lower extremities, the frequencies for TRI were lower than those for BI, and the frequencies for RF were lower than those for TA. The reason seems to be that there are more fast muscle fibers of TRI than for BI and more fast muscle fibers of RF than for TA as property of muscle contraction. When establishing the frequency of movement at each movement intensity level of 1RM, muscle contraction difference should also be taken into consideration in movement therapy.

T12.P34
EFFECTS OF FATIGUE ON VOLITIONAL AND MAGNETICALLY-EVOKED KNEE FLEXOR ELECTROMECHANICAL DELAY OF MALES AND FEMALES

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AIMS: Females are at five to eight times greater risk of anterior cruciate ligament (ACL) injury compared to male counterparts. Optimal functioning of the knee flexors is paramount to the dynamic stabilisation of the knee joint. Neuromuscular performance capabilities may be adversely affected by fatigue, however, the subsequent temporal effects on the evoked physiologic capacity of the system to initiate muscle force under these circumstances is yet to be established. The aim of this investigation was to examine the effects of an acute intermittent bout of maximal intensity static fatiguing exercise on the voluntary and magnetically-evoked electromechanical delay in the knee flexors of males and females.
METHODS: Assessments of volitional and magnetically-evoked neuromuscular performance of the knee flexors of the preferred leg of seven men and nine women were obtained prior to and immediately after two treatment conditions: (i) an intervention condition that required participants to perform a fatigue trial of 30 seconds maximal static exercise of the knee flexors of the preferred leg, (ii) a control condition of equivalent duration consisting of no exercise.
RESULTS: While absolute strength performance was preserved during the control task, the fatiguing exercise task elicited a reduction in absolute strength performance ($F_{(1,14)}$= 14.0, $p<0.05$), which was generally greater in males compared to females (265.1 (±52.0) N vs. 311.8 (±52.8) N [15% impairment] and 171.4 (±33.9) N vs. 190.8 (±48.6) N [10.2% impairment], respectively) (group mean score (±SD)). The fatiguing exercise task elicited a 19.3% impairment in volitional electromechanical delay performance (EMD_V) compared to baseline levels exclusively in females (61.9 (±19.0) ms vs. 51.9 (±13.1) ms, respectively) ($F_{(1,14)}$=5.9, $p<0.05$). A significant two-factor interaction associated with the mixed-model ANOVA showed that while absolute EMD_E perfor-

mance was preserved during the control task, the fatiguing exercise task elicited a potentiation (21% decrease) in magnetically-evoked electromechanical delay (EMD_E) latencies in both males and females ($F_{(1,14)}$=27.3, p<0.001) (see Figure 1).
CONCLUSIONS: Impairment to peak force capabilities, coupled with an increase in EMD_E latencies of the knee flexors may reflect an increased risk of ACL injury in the female athlete. Potentiation EMD_E following fatigue, however, may reveal aspects of compensatory mechanisms facilitating stabilisation of synovial joints during stressful exercise and a neuromuscular capacity that can be deployed during times of critical critical threat to the joint system.

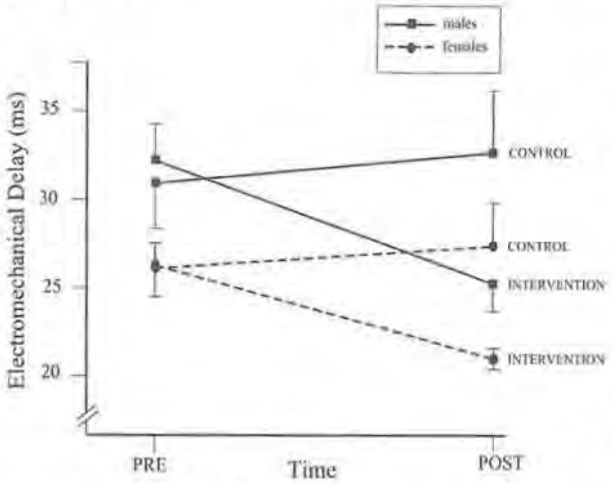

Figure 1. Effects of fatigue on the magnetically-evoked electromechanical delay performance (EMD_E) of the knee flexors (group mean±SD).

T12.P35
ELECTROMYOGRAPHIC COMPARISON BETWEEN INDIVIDUALS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND WITHOUT INJURIES DURING PERTURBATION EXERCISES

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AIMS: The goal of this study was to compare the electric activity of the muscles that stabilize the knee in different perturbation exercises of the individuals with ACL's reconstruction and individuals without lesion.
METHODS: Eight males (age 31,8±7 years; mean±SD), submitted to the ACL's reconstruction (using central third patellar tendon autograft) more than 30 months ago (34,8±13,7 months) and eight males individuals (age 32±7,3 years), without lesions, participated in this study. The maximum voluntary isometric contraction (MVIC) of each muscle (vastus medialis obliques, vastus lateralis, semitendinosus, biceps femoris and medial gastrocnemius) was measured. For the recording of the EMG signals an eight channel surface EMG system was used (EMG System do Brazil, São José dos Campos - SP, Brazil, Inc.). All raw EMG signals were bandpass filtered between 10 and 500 Hz, amplified (common mode rejection ratio >100 dB, overall gain 1000, noise <1 IV RMS), analogue-to-digital converted (12-bit) at a sampling rate of 1000. The electromyographic signal was quantified by the root mean square (RMS), and normalized by the MVIC. A general linear model procedure using a multivariate and univariate design was used to perform an analysis of the variance. The significance was set in 5% (p≤0.05).
RESULTS: It was found no statistically significant difference when it compared the % of MVIC of the knee muscles stabilizers in individuals with ACL's reconstruction with individuals without lesion, in different perturbation exercises. When analyzed the % of MVIC in each exercise, differences were observed between vastus medialis obliques and vastus lateralis of the group without lesion with the muscles semitendinosus and biceps femoris of the operated group (inclined and round plate, *balancin* and anterior-posterior roller-board) (p<0,05). In the group with ACL's reconstruction, the vastus lateral is the extensor muscle with higher activation in any of the analyzed exercises, while in the group control is the vastus medialis obliques muscle.
CONCLUSIONS: To perform specific activities in closed kinetic chain, individuals with ACL's reconstruction did not show differences regarding the % of MVIC of the studied muscles when compared with individuals of the same characteristics whose ligaments were normal.

T12.P36
THE RELIABILITY OF MAXIMUM ISOMETRIC NECK FLEXION AND EXTENSION STRENGTH IN HEALTHY MEN AND WOMEN

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AIMS: Muscular strength may be an important parameter in evaluating neck function in patients suffering from long-term neck pain. The first purpose of this study was to assess the test-retest reliability of the of a new simple isometric strength test of the cervical flexor and extensor muscles. The second purpose was to establish a normative material of the neck strength in healthy, normal subjects.
METHODS: 12 men and 18 women volunteered to participate in the study. Mean (range) values for age, height and body weight were 41.3 (24-64) years, 186.2 (177-195) cm and 91 (76-115) kg for the men and 39.7 (23-48) years, 169.6 (161-178) cm and 66.3 (54-95) kg for the women. All tests were completed with the subjects lying horizontally on a plinth. The flexion and extension tests were taken with the subjects in the supine and prone, respectively. The force was measured with a strain-gauge potentiometer attached to the floor and connected to head of the subject by means of a padded velcro headband. At each test, subjects did 4-5 maximum isometric contractions each lasting 2-5 s separated by 1-2 minutes of rest. The retest was completed 12-16 days after the first test, using identical procedures. Subjects were encouraged to maintain their regular daily living between test-occasions.
RESULTS: In our study, the coefficient of variation (CV) between test-occasions 1 and 2 was 8.6% for the isometric cervical flexor muscles test and 8.8% for the cervical extensor muscle test. The men produced 2.4 times more force in the maximum cervical flexion test than the women did (131.6 (76-193) versus 54 (32-76) N; P<0.00001). The relative difference among genders was somewhat less in the neck extension test as the men was 1.7 times stronger than the women (284.1 (180-411) vs 170.2 (101-224) N; P<0.00001). The difference in force production between the extension and flexion tests were 2.2 for the men and 3.2 for the women respectively, and this difference among genders was significant (P=0.0006).
CONCLUSIONS: The reliability was high for both the isometric flexion and extension test. The men were overall stronger than the women, but the difference between genders was larger in the cervical flexor than extensor muscles. The genders therefore differed with respects to the extension/flexion strength ratio.

T12.P37
SURFACE EMG VARIABLE ESTIMATES DURING UPPER LIMB DYNAMIC CONTRACTIONS. A COMPARISON BETWEEN AIR AND UNDERWATER ENVIRONMENTS

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AIMS: Previous works reported in the literature compared the behavior of sEMG signals in aerial and in underwater environment during dynamic contractions. Their results are contradictory. Some authors reported a decrease in the amplitude of the EMG variables when the measurement is performed underwater, and some others did not find such a decrease. One of the hypotheses that might explain these discrepancies is that the water resistance and the flotation effects could cause differences in muscle activation with respect to the aerial environment.
In this work, we propose a protocol for comparing three EMG variables (average rectified value -ARV, mean spectral frequency -MNF, and conduction velocity -CV) during cyclical movements in aerial and underwater environment.
METHODS: Ten males (age: 27.4±1.9 years; height: 178.1±4.9 cm; weight: 72.8±8.4 kg: mean±SD) performed, in about 100 seconds, ten isotonic cycles of flexion and extension of the right elbow holding a dumbbell in the hand (with a weight equal to 50% of the maximum voluntary isometric contraction, measured at 90° of elbow flexion). The movements were repeated in dry and in underwater conditions, with the right hand, forearm, and upper arm immersed. Air and water temperatures were the same (±0.5°C) and maintained at 33°C. Half of the subjects performed the movements first in air then in water and the other half did the opposite. In order to compensate the estimates for the flotation effects a further (individually calculated) load was added to the dumbbell. The joint angle of the elbow was monitored by an electrogoniometer. The surface EMG signal was acquired by an 8-electrode array connected to a multichannel electromyograph. The array was sealed with waterproof adhesive tape. The biceps brachii muscle (short head) was studied.
EMG variables were estimated from short signal epochs (125 ms) to minimize the effect of signal non-stationarity. Such a choice allows to record signals during an angular variation always lower than 3°. The epochs were centered at the joint angles of 40°, 50°, 60°, 70°, 80°, and 85° (being 0° the maximum extension). ANOVA for repeated measures was adopted (factors: joint angle, contraction type (flexion or extension), environments (air or water), and cycle number) looking for differences in the studied variables.
RESULTS: The statistical analysis revealed that, at efforts near 50% MVC with cyclic repetition at 0.1 Hz:
1. the "environment" factor does not affect sEMG variables;
2. the "cycle" factor (related to time and fatigue) affects all the variables ($p<0.001$), that is:
    a. ARV values increase with time (norm. rate of change: 0.56 ± 0.22 %/s);
    b. MNF values decrease with time (norm. rate of change: -0.25 ± 0.05 %/s);
    c. CV values decrease with time (norm. rate of change: -0.18 ± 0.03 %/s);
3. the greater the joint angles the greater are the MNF values ($p<0.001$).

CONCLUSIONS: Results clearly showed that, if the floatation effect of the limb is compensated for, no significant difference in the ARV, MNF, and CV estimates between air and water conditions can be observed. In addition, the rates of change of sEMG variables during fatiguing dynamic contractions were found significantly different from zero and their absolute values were found smaller than the values recorded on the same muscle during isometric contractions.

T12.P38
INVESTIGATION OF THE ADEQUATENESS OF JERK AS A MEASURE OF HAPTIC SENSING ABILITY FOR UPPER LIMB BY A HAPTIC DEVICE SYSTEM

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AIMS: We have developed a rehabilitation tool system utilizing the haptic device that is an application of virtual-reality technology. The haptic device can control a haptic sensations input quantitatively. We assumed that this system was possible to establish the quantitative assessment of level of haptic disorder with using the performance time and error quantity of haptic grip position in Root Mean Square value. Time and R.M.S. were measurement of performance capability of haptic perception for upper limb. Other than these, Jerk which was defined as the rate of change of acceleration, was used a measure of function of upper limb in view of motor control skill. Flash, T. et al. presented model of minimum-jerk that maximizing smoothness might be equated to minimizing the mean-square jerk in multijoint motion. The purpose of this study was to investigate the adequateness of jerk as a measure of haptic sensing ability for upper limb by a haptic device system.
METHODS: The subjects were 22 healthy elderly persons (mean age 67 years) participated with informed consent. They were all right-handed. The system consists of a haptic device, a display, a computer and software for testing and training. The haptic provides virtual haptic sensations (e.g. Friction) during operation. The subject tries to move the cursor responding to stimuli on the display. Wave tasks, which task was for subjects to move the cursor along sine wave shaped line, were given to the subjects. The subjects performed the tasks by right arm. During operation, the performance time (time) and the data of position of haptic grip were retrieved and stored in computer (the sampling time is 10 msec.), and then calculated error distance (Root Mean Square value; R.M.S.). Jerk value was calculated form obtained acceleration output of the system. The relationships between Jerk, Time and, R.M.S. was analyzed by Peason's correlation coefficient.
RESULTS: There was a significant negative correlation between Time and R.M.S. ($r= -0.69$, $p<.01$), also a significant negative correlation between Jerk and Time ($r= -0.79$, $p<.01$). A significant positive correlation between Jerk and R.M.S. ($r=0.78$, $p<.01$) was indicated.
CONCLUSIONS: The results suggested that Jerk was useful measurement of haptic sensing ability for upper limb using a haptic device system. But Jerk analyzed in this study was mean value through the wave task. And then there was probability that Jerk might not indicate characteristics of the wave task because of the direction of trajectory changed in this task. We considered that the improvement of analysis method for Jerk was essential to reflect the property of the wave task.

T12.P39
UPPER LIMB TREMOR FOR SHOULDER PATIENTS AND HEALTHY PERSONS

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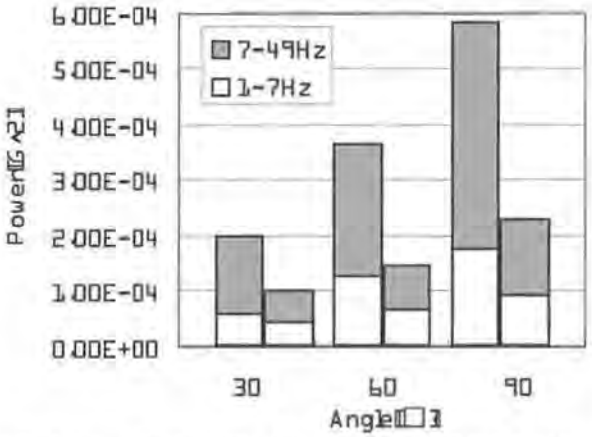
AIMS: The disorder of shoulder joint has been diagnosed by various techniques like endoscope and MRI, but the diagnosis was practically difficult. Physiological tremor (hereafter tremor) which is mechanical vibration of body part is known to prove the function of joint; that is, the function of muscles to move the body part around fulcrum of joint is detected by the activities of reflex nerve and central nerve with use of wave analysis of tremor. In the study, the function of shoulder joint for various shoulder disorders was evaluated by tremor of upper arm, and the characteristics were evaluated.
METHODS: Number of shoulder disorder were ten; six tendon breaks, two loose shoulders, one frozen shouder, two dislocations. Number of healty persons were 10 for control. Three kinds of shoulder angles were taken. Tremor was detected by acceleration sensor. Two kinds of tremor with direction of gravity and horizontal direction were measured. The power spectra were obtained. Since tremor has two frequency components, the total power spectra were obtained for two frequency ranges (1-7 Hz and 7-49 Hz).
RESULTS: Increase of shoulder angle showed increase of total power. Total power of Holozontal level was larger than that of vertical direction. Total power of healthy persons was large. Total power for disorder side of shoulder disorders was larger than that of healthy side of the disorder.
CONCLUSIONS: Tremor of vertical direction has been measured, but the horizontal component was not tried. In the study, tremors of both directions were measured. The increase of load of shoulder joint, that is, increase of shoulder angles denoted larger total power (i.e., larger mechanical vibration of upper arm). Distinction of total power between healthy and disorder persons is possible. Total powers in disorder and healthy sides for disorders were also discriminateed. The judgement by tremor in horizontal level was high compared with the in vertical direction. It was found that the evaluation of shoulder disorders was possible with use of tremor in both direction (vertical and horizontal directions).



Total power of horizontal level in shoulder angles for all shoulder disorders: left and right sides at each shoulder angle show the value for healthy persons and disored sidef of disorders. Black and white ars are the lower and higher frequency.

T12.P40
SHORT-TERM EFFECTS OF RESISTANCE TRAINING USING ELASTIC BANDS IN THE ELDERLY

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AIMS: The purpose of this study was to evaluate the effectiveness of an exercise program that we developed for the elderly. The program consists of 10 minutes of warm-up exercises, 2 sets of 15-minute "Arakawa theraban exercises" that we developed, and 10 minutes of cool-down exercises. The Arakawa theraban exercise consists of lower limb resistance training, and trunk flexibility and balance exercises, performed while watching the instruction video. Resistance was provided by elastic bands (Therabands™) of varying thickness.
METHODS: The subjects were 6 elderly men and 16 elderly women in Tokyo, 20 of whom live independently, and 2 of whom receive nursing care in an adult day-care centre. The mean±SD age was 78.9±6.9 years, and the age range was 60 to 89 years. The subjects performed the program as a community-based group twice a week for 3 months. Physical function and health-related quality of life (QOL) were evaluated before and after the 3-month period. QOL was evaluated from an SF8 questionnaire. The study was approved by the university ethics committee, and the subjects and family gave informed consent.
RESULTS: The following improvements were noted: maximal stride length (75.2±20.6→110.8±25.9%), 10 m walking speed (87.2±22.1→ 95.8±20.4 m/min), timed up and go (8.8±1.8→7.7±2.2 s), functional reach (19.8±5.7→7.0±2.2 cm), hand grip strength (19.9±6.0→21.2±6.2 kg), and leg extensor strength (65.8±6.4→98.8±7.6 Nm). There was no change in one-legged standing time with eyes open (seconds). Significant improvements were also seen in eight subscales, physical functioning, bodily pain, vitality, and mental health. The improvement was reflected in the physical component summary score.
CONCLUSIONS: The Arakawa theraban exercise program can be performed by a group of elderly while watching the video. This method may be ideal where there are many elderly. We will test this program in other facilities.

T12.P41
ANALYSIS OF HEART RATE RECOVERY TIME AT EXERCISE TESTING BELOW THE ANAEROBIC THRESHOLD LEVEL

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AIMS: Heart rate is used to check subjects' circulatory condition in rehabilitation medicine and fitness exercise. A lot of studies indicated that heart rate provided an improvement of subjects' physical fitness. However there are few studies about heart rate recovery time after the exercise testing below anaerobic threshold (AT) level. The purpose of this study was to investigate the influence of three exercise laod on the heart rate recovery time after bicycle exercise, loading under below the AT level.
METHODS: Subjects were eight healthy women volunteers with informed consent. the mean (SD) for age, height, and body mass were 20.3 (1.2) years, 158.2 (3.8) cm, and 49.9 (5.0) kg, respectively. They performed bicycle exercise: resting for 10 minutes, pedaling a exercise bicycle for 6 minutes, and resting for 15 minutes (during this duration, heart rate recovery time was measured.) and so on. The bicycle exercise load settings were three kind of folowing methods: 100% AT (test 1), 80% (test 2) and 60% (test 3), respectively. We recorded their heart rate throughout this entire trial period by heart rate monitor (s810, Polar Co.), then analyzed the influence of exercise laod settings to their heart rate recovery time. Heart rate recovery time was determind as follows, it is when a heart rate after the exercise is recovered within 1SD heart rate AT rest.
RESULTS: The mean (SD) of oxigen consumption and power of AT level were 14.7 (1.0) ml/kg/min, 50.7 (4.2) W, respectively. The mean for resting heart rate in test 1, 2, and 3 were 81.6 beats/min (test 1), 76.1 beats/min (test 2), 76.3 beats/min (test 3) (not statistically significant), and the mean for exercising heart rate were 118.5 beats/min (test 1), 101.5 beats/min (test 2), 96.4 beats/min (test 3) ($p<0.05$, statistically significant), respectively. Judging by the results of these heart rate changes, the increment magnitude of exercise load was appropriate to each subjects. The mean values for heart rate recovery time were 71.2 sec (test 1), 51.8 sec (test 2), 34.4 sec (test 3) ($p<0.1$, not statistically

significant). Heart rate recovery time (Y) and each subjects' AT (X1) and load (X2) showed a regression of Y=7.72 X1+1.95 X2-140 (r=0.60 and p=0.028, statistically significant). The regression was shown that it had the possibility to predict heart rate recovery time by the subjects' AT level and the magnitude of exercise load.

CONCLUSIONS: After the exercise with the constant time and low load, duration of the heart rate recovery time was affected by the subjects' AT level and the magnitude of exercise load. These findings showed what might use in rehabilitation medicine and fitness exercise.

Posture

POSTURAL RESPONSES TO PROPRIOCEPTIVE STIMULATION: DEPENDENCE ON STIMULUS DURATION

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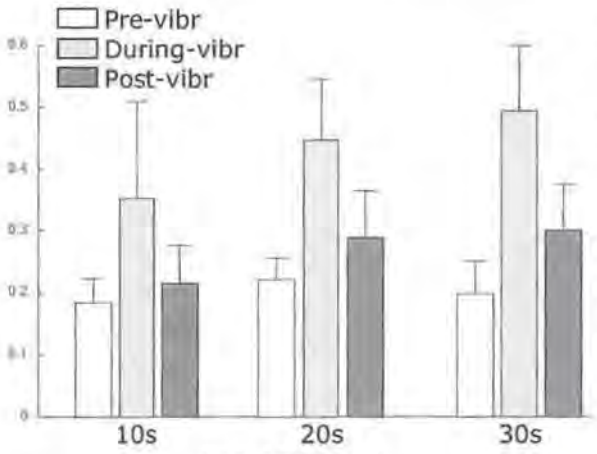
AIMS: Body lean responses to bilateral vibration of soleus muscles were considered in order to understand the influence of proprioceptive input from lower legs in human stance control, with the aim of investigating whether duration of proprioceptive stimulation can modulate the respective postural responses, and the presence of possible post-vibration effects, in terms of body alignment and body sway.
METHODS: Proprioceptive stimulation was applied on 9 healthy subjects by two systems based on small eccentric motors [1] placed on the soleus muscles by elastic cuffs. Frequency and amplitude of vibration were 60 Hz and 1 mm respectively. While subjects stood relaxed on a force platform, with eyes closed, vibration was activated after a 30 s of baseline, for 10, 20 or 30 s; then 30 s of post vibration were acquired. Postural responses were characterized by the centre of pressure anterior-posterior displacement (CoP-AP). The CoP-AP group-averages, in the 3 cases of different vibration duration, were considered to quantify body alignment; the CoP-AP root mean square distance (RMS) before, during and after vibration was computed as a measure of body sway. Additional trials with 120 s of post-vibration recording were preliminarily analyzed by a STFT time-frequency analysis to evaluate long-term post-vibration effects.
RESULTS: Soleus muscle vibration induced an initial, rapid backward body tilt that was followed by a further slower body lean; CoP-A group averages were found to linearly increase with time (slope ranging from -0.04 to -0.07 cm/s). The RMS of the CoP-AP was influenced by the presence of vibration of soleus and by its duration (see Figure). RMS during vibration (computed after a linear detrend) was larger than the baseline ($p<0.001$) in all the cases, and increased with duration of vibration ($p<0.01$ for 10 s compared to 20 s and 30 s vibration). When vibration stopped, body alignment quickly returned to the baseline configuration; RMS decreased compared to the vibration phase, but it remained generally higher than the baseline in all cases ($p<0.01$). RMS post-vibration increased with duration of vibration ($p<0.05$ for 10 s compared to 20 s and 30 s vibration). The time-frequency analysis in trials with 30 s of vibration and with 120 s of post-vibration showed a post-stimulus increase in the power of the CoP-AP, still present after 120 after vibration had stopped. The power became more spread over the signal bandwidth than it was before the vibration.



RMS of CoP-AP [cm]

CONCLUSIONS: Current findings show that influence on postural control of proprioceptive stimulations consists of direction-specific and time-dependent alteration of body alignment and body sway. Further, body sway was found to remain altered even after suppression of the stimulus and restoration of body alignment to the baseline, with interesting long-term post-vibration effects, dependent on duration of the proprioceptive stimulus.

[1] Polonyova A, Hlavacka F. Human postural responses to different frequency vibrations of lower leg muscles. Physiological Research 2001; 50: 405-410

GAIT INITIATION DIFFERS BETWEEN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY AND AGE-MATCHED CONTROLS

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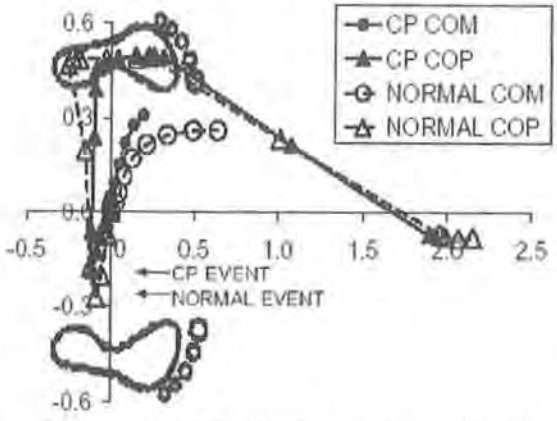
AIMS: The distance from the floor projection of the center of mass (COM) to the center of pressure (COP) during gait initiation has been found to differ between healthy adults and those with balance impairment [1,2], providing insight into dynamic balance strategies in older adults. The purpose of this prospective study was to determine if a similar difference exists between children with cerebral palsy and typically developing controls, and if a metric derived from the COM and COP displacement could be used to describe balance ability in these populations.
METHODS: An array of four kistler force platforms and a six-camera vicon 512 motion capture system were used for data capture. Thirty subjects (15 age-matched pairs) gave informed consent, donned a 36 target full-body reflective marker set, and were instructed to stand with each foot on a separate platform a comfortable distance apart. The COM of each subject was calculated using a full-body kinematic model modified for children. The COM-COP distance was measured at the greatest posterior and lateral cop displacement in the direction of the first swing limb (Figure). COMCOP distances were normalized using the subject's base of support (ankle-ankle distance). Normalized distances were grouped by initiating limb (dominant and unaffected, or non-dominant and affected limb) and diagnosis. Differences between and within subjects were compared using paired t-tests and were Bonferroni-adjusted for four pair-wise comparisons.
RESULTS: Normalized COM-COP distances in children with CP were found to be shorter than their pathology-free counterparts in both non-dominant ($n = 30$, $M_{N\text{-}DCP}=0.21$, $M_{N\text{-}DNORM}=0.33$, $p=0.018$) and dominant-side initiations ($n=30$, $M_{DCP}=0.18$, $M_{DNORM}=0.30$, $p=0.023$). COM-COP distances within subjects and between dominant and non-dominant initiations were not significantly different in either children with CP ($p>0.05$) or controls ($p>0.05$).
CONCLUSIONS: The smaller COM-COP distance found in the CP population suggests that the dynamic balance strategy used by these children is altered in response to inherent physical limitations imposed by the disease. A large COM-COP distance provides a greater moment-generating capability about the COM, providing more efficient control. However, as the distance between COM and COP increases, there are higher demands placed on the subject's strength and balance ability in order to contain their com displacement within their base of support. These data imply that children with smaller COM-COP distances have reduced ability to control their COM and that children with cerebral palsy are reticent to produce COM trajectories beyond their ability to control. Both populations showed no differences between sides in their COM-COP distances. This may be associated with the inherent bipedal nature of the gait initiation task, where impairment on one side influenced the COM-COP distance regardless of the initiating leg. This metric may prove to be a useful physical measure for determining balance ability in the pediatric CP population.

[1] CJ Haas, et al, Arch Phys Med Rehabil 2005; 86:2172-2176
[2] M Martin, et al, Phys Ther 2002; 82:566-577

Support provided by the Children's Hospital Research Institute



Representative COM and COP trajectories normalized by base of support during gait initiation in a child with cerebral palsy compared to control

RELATIONSHIP BETWEEN DYNAMIC BALANCE AND STOOPING POSTURE DURING GAIT IN ELDERLY PEOPLE

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AIMS: What triggers a stooping posture in elderly people? Generally the stooping posture is regarded as a result of vertebral deformity due to osteoporosis, but the vertebral deformity may not always lead to stooping. We hypothesized that the reduced recovery time from a fall may trigger the postural change during gait, so we designed a new device to measure dynamic balance that would reflect the speed of recovery from the stability limit. The present study examined the relationship between dynamic balance and forward trunk leaning during gait in elderly people. Additionally we examined the relationship between the forward trunk lean and musculoskeletal functions.
METHODS: Subjects were 19 healthy elderly people (10 female and 9 male; mean age = 70.1 ± 5.4 years) who were recruited from the local community. Dynamic balance was measured using a specially designed force platform that slides on two rails. The platform helps the subject to transfer his or her weight from heel to toe or from toe to heel when performing voluntary anterior-posterior (AP) sway of the center of pressure (COP) on the platform. Wearing a safety harness, subjects performed voluntary cyclic AP sway standing on the sliding platform, which contained three load cells to measure vertical ground force. Data were recorded at 100 Hz, and the associated COP was then computed. An auditory metronome guided subjects to sway the COP at 0.5 Hz. Once the subject swayed rhythmically, force data were recorded for 10 seconds. Time series were analyzed for each trial corresponding to COP sway. COP amplitude was calculated using the distances between the peaks and the valleys, and duration was defined as the times between the peaks. The calculated values were averaged across three trials per subject. The degree of thoracic kyphosis, lower-extremity ranges of motion, trunk flexion and extension isometric strengths were used as indicators of musculoskeletal function. For gait analysis, subjects were asked to walk on a treadmill at a comfortable speed. To represent the trunk lean during gait, the angle between the trunk segment and pelvic segment in the sagittal plane was computed.
RESULTS: The mean forward trunk lean was 12.4 ± 5.3 degrees during gait, and the range was from 1.5 degrees to 22.9 degrees. The value of mean COP amplitude normalized to foot length was 0.73 ± 0.09, and the mean duration was 2.6 ± 1.4 seconds. Elderly subjects who showed longer duration of sway tended to lean more during gait ($r = 0.471$, $p = 0.042$), but forward lean was not correlated to other variables, such as the degree of thoracic kyphosis, any of the ranges of motion or muscle strength values in terms of trunk flexion and extension.
DISCUSSION: If subjects' movement is synchronized with auditory cues, the duration of swaying comes to 2.0 seconds. Elderly subjects in this study could not maintain the pace, and the mean value of swaying in our elderly subjects showed a longer duration. The extended duration indicates that it was difficult for elderly people to shift their weight or to recover from the stability limit so quickly. We conclude that this poor balance control was related to postural change during gait in elderly people.

FLEXED POSTURE IN ELDERLY: CLINICAL AND INSTRUMENTAL ASSESSMENT AND EFFECTS OF PHYSICAL ACTIVITY PROGRAMS

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AIMS: Evaluate correlation between flexed posture and motor function, disability, quality of life, osteoporosis and spine pain in elderly. Evaluate the effects of a specific physical activity program for flexed posture in comparison to a nonspecific traditional physical activity program.
METHODS: This is a double-blind, two-arm, randomized clinical trial conducted for 6 months. We examined 34 elderly subjects, 28 females and 6 males, with mean age 70.9 years (SD 5.1, range 65-84). exclusion criteria were: severe obesity (BMI>30), MMSE<24, NYHA class>1, neurological deseases, SPBI 1 item=1, secondary osteoporosis. Elderly population was characterized by a geriatric multidimensional assessment including: anthropometrical data, pain assessment, history of falls, muscular strength and length, severity of flexed posture (standing occiput-to-wall distance), Comorbidity Severity Index, performance test: Short Physical Performance Battery, Mini Mental State, Geriatric Depression Scale, Nottingham Extended Activities of Daily Living Scale, Multidimensional Fatigue Inventory, Barthel Index, muscular test and flexibility test. Instrumental assessment of posture was realized using a stereophotogrammetric system VICON 612 (Oxford UK). Measurement of the lower spine (L2-L4) and hips DEXA bone densitometry was done with norland XR36 densitometer (Norland Corp. Fort Atkins, Wisconsin, USA). The randomization was made into two groups: specific physical activity program following Sinaki approach and nonspecific traditional physical activity program. Exercise program was performed for one hour twice per week for 6 months. All measurements were conducted at baseline and 3 and 6 months.
RESULTS: Twenty-three of the participants completed the study, 15 subjects in the specific program and 8 in the nonspecific. In the first evaluation, the severity of flexed posture was classified as mild in 6, moderate in 20, and severe in 8 patients. There were no differences between flexed posture groups for osteoporosis, number of falls and spine pain. The severe flexed posture group was significantly different from the moderate and mild flexed posture groups in the following categories: muscle impairment (weaker spine extensor muscles and shorter pectoralis muscles), motor function (lower score in the Short Physical Performance battery), disability (lower score in the Nottingham Extended Activities of Daily Living Scale and Barthel Index), quality of life (lower score in the Mini Mental State and in the Multidimensional Fatigue Inventory) and instrumented assessment of posture (higher trunk flexion, hip flexion, knee flexion and ankle dorsiflexion). In the second evaluation after physical activity programs, significant improvements were noted in both groups: Nottingham Extended Activities of Daily Living Scale, Mini Mental State, Multidimensional Fatigue Inventory, Geriatric Depression Scale. More significant improvements were founded in the specific physical activity group in comparison to the nonspecific traditional physical activity group, concerning: standing occiput-to-wall distance, instrumental assessment of posture (higher hip extension), muscular strength and length (stronger spine extensor and abdominal muscles and longer pectoralis muscles).
CONCLUSIONS: The severity of flexed posture is correlated to motor function, disability and quality of life. A specific physical activity for flexed posture determines more significant improvements in elderly in comparison to a traditional physical activity, concerning posture and motor function. Instrumental assessment using a stereophotogrammetric system is useful to study flexed posture and compensation strategies.

T13.P01
COMPARATIVE STUDY OF POSTURE AND ELECTROMYOGRAPHIC ACTIVITY BETWEEN TEMPOROMANDIBULAR DYSFUNCTION AND HEALTHY SUBJECTS

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AIMS: The purposes of this study were: (1) to compare the sagital and frontal head and shoulders posture of temporomandibular disorders (TMD) and healthy subjects; (2) to compare the electromyographic (EMG) activity in anterior temporalis and masseter muscles of two groups of volunteers during mastication.
METHODS: First of all, anamnestic questionares and clinical evaluation were performed to share the sample in one group of 16 TMD subjects and one group of 16 healthy subjects. All subjects had full dentition and bilateral Angle Class I occlusion. The EMG recordings were conducted over three non-consecutive days of the same week with the subjects in the orthostatic posture. Four pairs of circular passive surface electrodes joined to preamplifiers, with an 1 centimeter interelectrode distance, were used to register the anterior temporalis and masseter muscles chewing activity simultaneously for 10 seconds and maximal voluntary clenching for 5 seconds. The EMG signal was normalysed and maximum instant (IMAX) and active period (ON) were calculated and analysed for each muscle during mastication cycle. Frontal and lateral photographs were taken in natural posture with the subjects standing up. The following anatomical landmarks were palpated and marked: both acromiones, temporomandibular joints (TMJ) and ear lobes; and two angles were obtained from each view. The frontal angles were formed by biacromial line (A1) and TMJ line (A2) in relation to the true horizontal; and the sagital angles were formed by right acromion (A3) and ear lobe (A4) to the true vertical. Statistical testing was performed to compare the differences between the groups.
RESULTS: Analyzing the posture, there was no significant differences in the 04 angles obtained between the TMD and the healthy groups. In the EMG recordings, TMD group presented a significative higher IMAX in the right anterior temporalis muscle in relation to healthy subjects group.
CONCLUSIONS: There was not found a major prevalence of head and shoulders postural alterations in TMD subjects.
The EMG activity was significantly higher in right anterior temporalis muscles of TMD subjects.

T13.P02
ANALYSIS OF THE POSTURAL AND CRANIO-CERVICAL DYSFUNCTION PROFILE IN DYSPHONIC WOMEN

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AIMS: Some clinicians have observed that dysphonia may be related to dysfunctions of the spinal column. However, it has not yet been scientifically proved whether there is any correlation between them. Thus, the aim of this study was to investigate the postural profile and the presence of cranio-cervical dysfunction in dysphonic women.
METHODS: A selection was made of 31 volunteers with a mean age of 31.25±8.14 years of age, who were divided into two groups: Experimental group, formed by 19 dysphonic women, and the control group, composed of 12 clinically normal women. In order to select the experimental group, a vocal and oto-rhinological assessment was made of dysphonic women registered for vocal treatment at the Voice Sector of the Speech Therapy Clinic of the Methodist University of Piracicaba - UNIMEP. Whereas, for the control group a speech therapy assessment was made to eliminate the presence of dysphonia. After selecting the sample, the volunteers were submitted to two assessments: Index of cranio-cervical dysfunction and photometry in the same region. Initially the cranio-cervical dysfunction index described by Wallace and Klineberg (1993) was applied. Afterwards photographs were taken in the saggital position, by means of a photographic camera model *Sony Cyber-shot 3.2 megapixels*. In order to do this, a cord symmetrograph and foot positioner were used, which were positioned at 70 cm from the wall and 110 cm from the tripod with the photographic camera. The photographs were filed and analyzed in the *Software Corel Draw* 8.0, in which it was possible to determine the anterior angle formed between the seventh cervical vertebra and the tragus. To analyze the data, the Shapiro-Wilk tests were used, with the purpose of testing the normality of the sample and the Student-t test to compare the control group with the experimental group. This present study was approved by the UNIMEP Ethical Committee under Protocol 89/2003, and the research was conducted in accordance with the National Health Council (Resolution 196/96).
RESULTS: The results with reference to photometry showed that there was no significant difference between the mean values of the position of the head in the saggital plane between the studied groups (p=0.52022). The cranio-cervical dysfunction index showed that of the 19 dysphonic women evaluated, all presented with cranio-cervical dysfunction, the values being 37% mild dysfunction, 47% with moderate dysfunction and 16% severe dysfunction. Whereas in the control group 100% of the volunteers presented with mild dysfunction.
CONCLUSIONS: Under the experimental conditions used, it was possible to conclude that there is no difference in the position of the head in the saggital plane between the analyzed groups. However, dysphonic women presented with more accentuated cranio-cervical dysfunction than the women in the control group.

T13.P03
THE INFLUENCE OF HIGH HEEL SHOES ON LUMBAR LORDOSIS ASSOCIATED TO THE LUMBAR MUSCLES AND GASTROCNEMIUS

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AIMS: Investigate through surface electromyography the referred fatigue point and the electromyographic behavior of principal postural muscles in dental work in dental students of different specialties in work posture.
METHODS: The referred fatigue point and the activity of muscles deltoid (medial portion), trapezius (upper portion) and cervicals, were investigated through surface electromyography in 30 dental students with age between 19 and 24 years in work posture, divided in 4 groups of 3 different specialties and 1 non-dentist group.
RESULTS: The muscles more actives and present fatigue signals were the M. Trapezius and M. Deltoid respectively, in the dentist groups. In the non-dentist group, the cervical muscles presented less activity in relation to others muscles. The referred fatigue was first manifested in a dentist group, independent of specialty.
CONCLUSION: The maintenance of ill-posture by prolonged periods, as dental work, take the fatigue and pains muscles, even to a chronic muscle pain. As preventive form and treatment suggest small pauses during the work, with exercises of stretching and postural corrections.

T13.P04
EFFECTS OF WHIPLASH-ASSOCIATED DISORDERS ON POSTURAL CONTROL DURING SITTING

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AIMS: When subjected to translations of the support surface, healthy persons display typical strategies to stabilize their posture, whether they are standing or sitting. Persons with whiplash associated disorders (WAD) often report symptoms such as dizziness and are likely to have deficits in postural stability. However, the effects of WAD on the stabilization mechanisms of the sitting posture are not well known. The goal of this study was to compare the postural stabilization characteristics of seated healthy subjects to those of WAD individuals following translations of the support surface in the anteroposterior direction.
METHODS: Healthy and WAD subjects were tested on an adapted ergonomic chair that was firmly mounted onto a movable support surface powered by electrohydraulic actuators. They were subjected to a randomized sequence of forward, backward, and no perturbations, with 5 trials in each condition. The perturbation stimulus consisted of a pseudo-ramp signal of 15 cm in 500 ms, with a peak velocity of 0.3 m/s. Electromyography (EMG) of eight trunk and neck muscles was recorded bilaterally using bipolar surface electrodes (Noraxon). EMG onsets were identified as signals surpassed two standard deviations above baseline for a duration of at least 25 ms. Reflective markers were placed on anatomical landmarks of the head, trunk and arms and their 3D positions were recorded using a 6-camera VICON motion capture system. The head and trunk segment flexion/extension angles were computed. The segmental centers of mass (COM) of the head, upper thorax, lower thorax, and abdomen were also computed. Angular and COM onsets were identified when displacement velocity surpassed 5% of its maximum.
RESULTS: In healthy subjects, activation of flexor muscles coincided with inhibition of extensor muscles regardless of direction of translation, except that the latencies of muscle activations were 400-600 ms earlier for forward as compared to backward translation. In some cases, extensor inhibition was preceded by a burst of activity during backward translations. In contrast, onsets of COM displacements were 10-50 ms earlier for backward perturbations, thus reflecting different compliance in body mechanics. Most WAD subjects did not show reciprocal inhibition of extensor muscles, while no remarkable difference in muscle latencies was observed.
CONCLUSIONS: The automatic postural responses to unexpected surface translation during sitting in healthy individuals consist of simultaneous activation of ventral muscles and reciprocal inhibition of dorsal muscles. The absence of reciprocal extensor inhibition following perturbation in WAD subjects may be indicative of pathological postural stabilization mechanisms.

T13.P05
PRELIMINARY STUDY OF CENTER OF PRESSURE-FEEDBACK CONTROL FUNCTIONAL ELECTRICAL STIMULATION BALANCE TRAINING SYSTEM IN STROKE

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AIMS: The ability for smooth transfer and safe ambulation is based on a sufficiently stable standing balance. The aim of this study is to verify the effectiveness of a self-developed center of pressure (COP)-feedback control functional electrical stimulation (FES) balance training system in stroke patients. We expected more effective standing balance training by using this FES system than by applying traditional balance training.
METHODS: Sixteen stroke patients were divided into 2 groups randomly. All of the patients received traditional rehabilitation with routine programs. Eight subjects received additional balance training by using this FES system (group A) 3 days per week for 2 weeks. Another 8 subjects received additional traditional balance training without FES (group B). The self-developed COP-feedback control FES balance training system stimulated quadriceps femoris, hamstrings, anterior tibialis and gastrocnemius timely and individually according to the COP-feedback signal by using a fuzzy controller. Weight transfer capability, COP maximal displacement and weight bearing on the hemiplegic lower limb were measured and analyzed before and after two-week training respectively.
RESULTS: The preliminary results show that improvements of standing balance are significantly better in group A than in group B in all of the mentioned measures. After training, weight transfer capability in group A showed a significant increase ($p<0.05$), while the group B showed no change. COP maximal displacement showed a significantly increase in both group ($p<0.05$). Nevertheless, it is significantly more increased in group A than in group B ($p<0.05$). Weight bearing on the hemiplegic lower limb is more improved in group A than in group B ($p<0.05$). Comparing with traditional approaches, the significant therapeutic effects of this COP-feedback FES system are demonstrated.
CONCLUSIONS: Based on the knowledge of the lower extremity EMG of normal subjects during standing, we developed a COP-feedback control FES balance training system. The preliminary results showed that the usage of the self-developed COP-feedback control FES balance training system can improve standing balance of the stroke patients effectively.

T13.P06
POSTURE AND SPINE MODIFICATIONS AFTER TOTAL HIP JOINT REPLACEMENT: EFFECTS OF LEG LENGTH DISCREPANCY CORRECTION

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AIMS: Following total hip joint replacement (THJR), the durability of a prosthesis is limited by: wearing of frictional surfaces and loosening and migration of the prosthesis-cement-bone system. Literature review witnesses biomechanical studies focused mainly/only on hip functional state while none of them approached leg length discrepancy (LLD), pelvic obliquity, posture unbalancing or spine related problems after THJR. Conversely, these latter could be critical elements for surgery and rehabilitation success, given the possible induction of asymmetric loading patterns. This study presents the results obtained by using a recently proposed methodology, to measure 3D subject posture balance and spine morphology and to evaluate its usefulness in individual therapy tuning/follow up, as well as in medium and long term spine problems prevention after THJR.
METHODS: The methodological approach is to evaluate each subject's posture by means of 3D opto-electronic device, force platform and baropodographic measurements.
90 subjects after THJR aged 24 to 78 (μ=66.5±9.3) years have been included in this study. The subjects have been evaluated in two different epochs: when they were allowed to load prosthesised lower limb and after 3 months since they were discharged from our centre. A 27 passive marker body landmarks labelling protocol has been applied to measure the complete 3D skeleton posture and spine morphology/stiffness both in static and in dynamic condition. At least 500 3D measurement per each analysed orthostatic posture in different conditions (indifferent, under foot wedge lower limb discrepancy correction) have been averaged together per each session.

RESULTS: 77/90 patients (85.6%) presented a LLD, pelvic obliquity and posture unbalancing. More than 90% of this group showed an overall postural re-balancing induced by the use of simple underfoot wedge (μ=17.2 ±7.1mm). 70/77 patients (90.9%) needed wedge under the healthy side showing the surgical intervention produced a leg lengthening. 60/90 (52 LLD) patients underwent up to now to control and three different patient's subgroups have been classified: patients who wore the suggested wedge (63.4%, group A); patients who wore a shorter than suggested wedge (23.1%, group B); patients who did not wear the suggested wedge (13.5%, group C). Group A presented a well balanced stabilised posture, improving all the considered quantitative parameters (100% improvement). In the group B, a similar behaviour can be observed, but a percentage of the subjects paid the incomplete lower limb discrepancy correction with a worsening of spinal curve (66.7% improvement). Group C presented a generalised significant worsening of their postural balancing, mainly due to an increase of spinal deformity (16.7% improvement). Prosthesis settlement was found not to be unusual. 28/52 (53.8%) patients presented such phenomenon and their wedge size had to be changed accordingly: wedge size reduction (μ=5.7 ± 2.9 mm).
CONCLUSIONS: After THJR more than 85% of our sample presented a LLD that had to be compensated. The induction of a correct re-balancing seems to be a useful approach in order to reduce risks of lower limb load disparity, asymmetric locomotion and spinal deformities generation. More than 53% of patients showed a prosthesis settlement indicating the necessity of follow up. The presented methodology showed to be useful as a clinical tool.

T13.P07
EFFECTS OF DENTAL OCCLUSION ON DYNAMIC BALANCE

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AIMS: The authors considered that if dental articulation played an important role in improved dynamic balance, dental occlusion and denture fitting would be involved with rollover in the elderly. This study was conducted to examine the hypothesis that "dynamic balance was improved in a tooth-biting condition".
METHODS: The subjects were 30 healthy young adults with no abnormal function of balance, the jaw or oral cavity (15 males and 15 females; mean age: 20.3±1.6 years old). The activity of the masseter muscle was measured using an EMG system (SX230, Biometrics Ltd., UK) to determine the condition of dental occlusion. The balance measurement was conducted using the Equi Test System® (MPS-3100, NeuroCom, USA). The latency period (ms) from immediately after disturbance load to the beginning of righting action was determined observing the center of foot pressure. These data were compared while biting and not biting. The latency period (response variable) was analyzed using a mixed-effects model with dental occlusion, back and forth, grade, interaction between dental occlusion and back and forth, interaction between dental occlusion and grade, and random effects of cases as explanatory variables. The significance level was set as 5%. SAS version 8.2 (SAS Institute Inc, Cary, NC) was used.
RESULTS: Using the minimum disturbance stimulus that had been established with the Equi Test System®, the estimated least-square mean latency periods were 129.58 and 131.17 ms for biting and not biting, respectively, with no significant difference (1.58; p=0.3541). However, following the medium disturbance stimulus, the mean latency periods for biting and not biting were 123.08 and 132.50 ms, with a difference of 9.42 ms (p<0.001). Following the maximum disturbance stimulus the mean latency periods were 122.17 and 136.08 ms, with a difference of 13.92 ms (p<0.0001).
CONCLUSIONS: We demonstrated that the least-square mean latency periods for biting and not biting changed inversely as the disturbance stimulus increased; i.e., the differences were increased with the disturbance stimulus. These results suggest that the response to recover the balance against unexpected disturbance stimulus was improved with biting, compared with not biting. These results also validated the hypothesis that "the balance ability including preventing rollover was superior with biting compared to that while not biting".

This study was conducted with the approval of Tokyo Metropolitan University of Health Sciences IRB with financial assistance from the Ministry of Education, Culture, Sports, Science and Technology, the Grant-in-Aid for Scientific Research (Study No.: 16700486).

T13.P08
DYNAMIC BALANCE CONTROL IN TRANSFEMORAL AMPUTEES; INDIVIDUAL CONTRIBUTION OF THE PROSTHESIS SIDE

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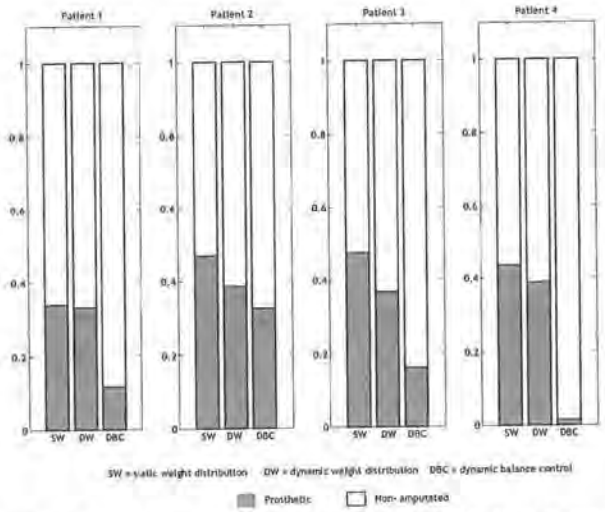
AIMS: A major goal in the rehabilitation of lower limb amputees is to regain effective postural control. Particularly in transfemoral amputees this requires complex adaptation strategies in both the prosthesis side and the non- amputated side. This study explores the use of a new developed method (van der Kooij et al., 2005) to assess the Dynamic Balance Control (DBC). Unlike methods using weight distribution as a measure of balance, this method determines the individual contribution of both legs to postural control during perturbations.
METHODS: Four unilateral transfemoral amputees were included. Subjects stood on a force platform mounted on a motion platform and were instructed to stand still. The experiment consisted of 1 static and 3 perturbation trials of 90 seconds each. During the static trial the platform did not move. During the (dynamic) perturbation trials, balance responses were elicited by continuous random sagital platform movements consisting of a sum of sinuses (ranging from 0.06-2.37 Hz). Weight distribution during the static (SW) and the dynamic perturbation trial (DW) were calculated by dividing the average vertical force below the prosthesis foot by the sum of forces below both feet. The Dynamic Balance control (DBC) represents the ratio between the stabilizing mechanism of the prosthetic leg to the stabilizing mechanism of the non-amputated leg. For both legs, the stabilizing mechanism were calculated from the corrective ankle torques, in response to body sway (assessed by the movement of CoM). The stabilizing mechanisms were represented by their frequency response function of body sway to corrective torque. The relative contributions (DBC) of both legs were averaged over all the perturbation frequencies.
RESULTS: All patients showed a clear asymmetric weight baring in favor of the non-amputated leg (see Figure). However the DBC ratio showed that the contribution of both legs to balance control was even more asymmetric.
CONCLUSIONS: The contribution of the prosthetic leg to balance was much smaller than its contribution to weight bearing. This implies that the contribution of the prosthetic leg is not a mere reflection of the weight distribution. This method could help to evaluate a lower limb amputee's ability to compensate for loss of his leg and the necessity for (and efficacy of) balance training. Furthermore, the method could clarify whether the introduction of more advanced prosthetic legs lead to a greater contribution to balance of the prosthetic leg.



van der Kooij H, van Asseldonk E, van der Helm FCT (2005) Comparison of different methods to identify and quantify balance control. Journal of Neuroscience Methods 145:175-203.

T13.P09
AGING EFFECT ON POSTURAL MODULATION IN THE TIBIALIS ANTERIOR STRETCH REFLEX

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AIMS: It has reported that the stretch reflex excitability of the TA muscle is enhanced in standing compared with other postures, although background electromyographic activity is silent. From a viewpoint of relation to postural control, it is interesting to reveal how such a reflex modulation is affected by aging. The purpose of this study is to investigate aging effect to postural modulation of the TA stretch reflex excitability.
METHODS: Fourteen older subjects and nine younger subjects who had no history of neurological disorders were participated in this study. Stretch reflex electromyographic (EMG) responses in the TA were elicited by imposing a quick plantar flexion mechanically in standing (ST) and sitting (SIT) condition. The stretch reflex responses were evaluated by the proportion of mean amplitude of SIT to ST (SIT/ST ratiio). In older subjects, some subjects showed significantly greater back ground EMG in ST compared with in SIT. Therefore we divided older subjects to two group: older group 1 (older1: who didn't show difference between postural conditions) and older group 2 (older2: who showed difference).
RESULTS: Results showed that the SIT/ST ratio was significantly greater in both older groups than in younger group (older1 vs. Younger: 80.9±16.0 vs. 25.3±5.4 %, older2 vs. younger: 81.8±11.5 vs. 25.3±5.4 %, $p<0.05$), although there were no difference between two older groups.
Fig. 1 illustrates a typical example of the stretch reflex EMG responses elicited in each postural condition. As clearly shown, two older groups lack the ability to modulate the reflex responses according to conditions.
CONCLUSIONS: The present results revealed that the TA stretch reflex excitability is kept high during sitting in older groups, whereas it is reduced in younger group. This suggests that elderly people lack the ability to modulate the stretch reflex excitability in the TA muscle with their postural conditions.

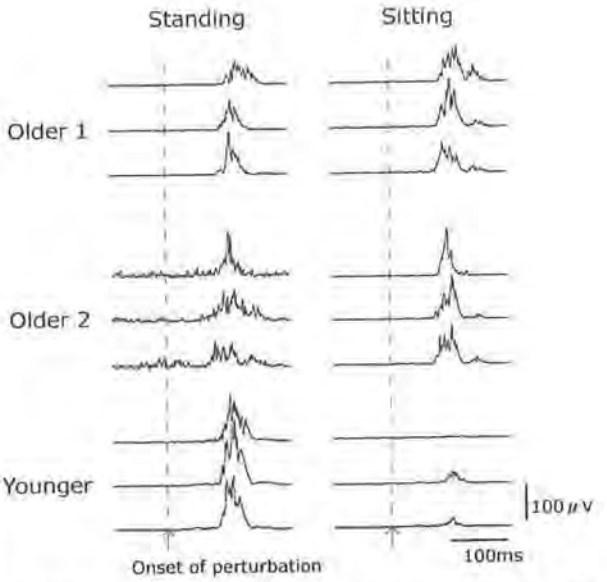

Fig. 1 Typical example of the stretch reflex responses for older and younger subjects in the TA muscle in standing and sitting conditions. Older 1 is a subject who didn't show different back ground EMG (BGA) in the SOL between conditions. Older 2 is a subject who showed BGA difference.

T13.P10
AGING EFFECT ON COHERENT ACTIVITIES OF BILATERAL SOLEUS MUSCLES DURING QUIET STANDING

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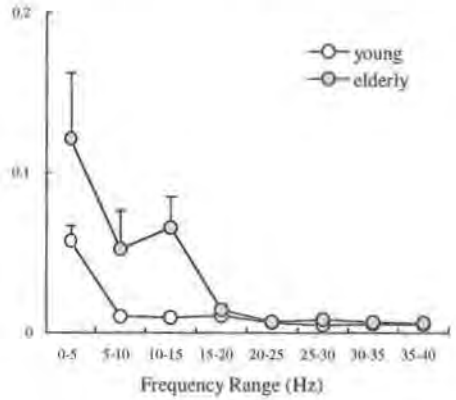
AIMS: The physiological tremors around 8-12 hz has been found in soleus muslces during quiet standing (Mori 1973, Masani et al. 2001). However, its physiological origin and functional role of the tremor are unknown. In order to investigate the tremor deeply, the aims of this study were 1) to investigate the synchronization between the right and left tremor using a frequency domain analysis, and 2) to investigate the influence of aging on the tremor synchronization.
METHODS: Twenty-five young healthy subjects (young group; 26.8±4.3 years) and 12 elderly healthy subjects (elderly group; 67.7±4.6 years) were instructed to stand quietly for 90 seconds on a force platform. Five trials were performed with a sufficient rest between the trials. The EMGs from the bilateral soleus muscles were recorded. Cross-spectral analysis was applied to investigate the correlation between the muscles in the frequency domain. For each group, the averaged coherence was calculated for every 5 Hz from 0 to 40 Hz. The differences among groups and among frequency ranges were tested using two-way and one-way repeated ANOVA follwed by a Tukey-Kramer post hoc test.
RESULTS: The coherence reached a statistically significant level in wide range of frequencies (up to 30 Hz), and the phase values were close to zero. Especially, the coherence showed large components in 0-5 Hz in both groups, which corresponded to balance regulating acitivity. Additionally, a secondary peak was found in 5-15 Hz, which corresponded to tremor. The coherence in this Frequency range tended to be laeger in elderly than young. Two-way repeated ANOVA showed the significant main effects for group and frequency factors, and the significant interection between the two factors. The comparison among frequency ranges for each group showed that the value of 0-5 Hz was larger than the values of the other frequency range in young group, while

there was no signifficant differences beween the values of 0-5, 5-10, and 10-15 Hz in elderly group. The comparison between groups for each frequency range showed that the value of elderly group was significantly larger than the value of young group in 0-5, 5-10, 10-15, and 25-30 Hz.



Average coherence in each frequency range for each group.

CONCLUSIONS: This study demonstrated that the tremor shynchronizes in both legs, although the shynchronization was clear in elderly compared to young. The result suggests that aging enhances the tremor shynchronizing mechanism.

Masani K, et al. The 31st Annual Meeting Society for Neuroscience, 2001.
Mori S. J Neurophysiol 36:458-471, 1973.

T13.P11
MOTOR CONTROL STRATEGIES TO MAINTAIN BALANCE IN ELDERLY SUBJECTS EVALUATED USING WAVELET TRANSFORM

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AIMS: Postural control is provided by complex interactions among proprioceptive, visual, vestibular and somatosensorial systems. Aging has been shown to affect all of these systems causing a poor balance in elderly subjects. Elderly subjects present serious problems due to poor balance such as falls and fractures which increase economical costs in health care. Balance evaluation has been of interest for clinicians and researchers because provides several applications such as predictor of falls, fractures index, and as indicator of treatment success when balance and proprioceptive training has been performed. The objective of this study was evaluate balance in elderly people using Wavelet Transform (WT) in order to provide a new tool to establish normal data for each gender in this population.
METHODS: Balance was evaluated in a probabilistic sample comprised of 50 male and 50 female with an average of 78 and 77 years respectively using a posture platform device. The evaluation consisted of three phases. In the first phase, the subject was asked to maintain the center of pressure (CoP) in the base of support for 30 seconds while a visual feedback of the position of the center of pressure was provided through a computer screen. The second phase was similar to the first phase but the subject had to keep his/her eyes looking to the front without visual feedback, and the last phase was similar to the previous one but with eyes closed. Signals obtained from the diplacement of center of pressure during the three tests for all subjects were analyzed by the Wavelet Transform in order to determine the intensity of each band (4 Hz, 2 Hz, 1 Hz, 1/2 Hz, 1/4 Hz 1/8 Hz and 1/16 Hz) for each gender. The Romberg index was calculated for each gender. SPSS statistical Program was used to evaluate differences in Romberg Index between females and males.
RESULTS: Greater levels of total relative energy were obtained in men when compared with women with eyes closed and eyes open phases. Romberg Index had a normal distribution with a mean of 135.4% (DS: 41.9%). No significant differences in Romberg index between females (124.2%) and males (140.6%) were found ($p>0.05$). However, there was a tendency for women to have lower Romberg Index values.
CONCLUSIONS: Greater levels of energy obtained with eyes open as well as eyes closed in men could be understood as a difficulty to maintain balance due to a poor interrelationship among visual, vestibular and proprioceptive systems in elderly male subjects. Women obtained lower levels of Romberg index which could indicate that women rely more in the visual system to maintain their balance. This could be associated with a major number of falls and fractures in elderly females.

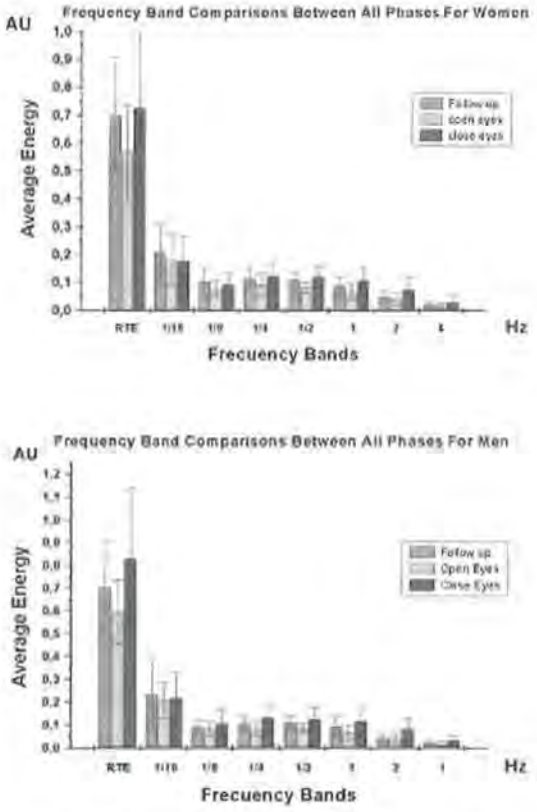

Figure shows all frequency bands and average energy during the test for females and males.

T13.P12
DIFFERENT BALANCE STRATEGIES OF ELDERLY AND YOUNG PERSONS SHOWN BY NONLINEAR ANALYSIS

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AIMS: In Japan, the rate of falling elderly persons of more than 75 years old is about 20-30%. Reduced postural stability is a risk factor for falls in elderly persons. Medial-lateral postural instability has recently been identified as a risk factor for falls among the elderly population. Therefore, this study uses nonlinear analyses to compare medial-lateral postural stability between elderly and young persons.
METHODS: Subjects are healthy elderly persons (mean age 78, n=13) and healthy young persons (mean age 24, n=13). Anterior-posterior (A/P) and medial-lateral (M/L) COP data were

measured using a gravicorder (anima, G620) with a 200-Hz sampling rate during quiet and lateral-reach standing for 30 s with eyes open. Fractal dimensions and the largest Lyapunov exponent of A/P and M/L COP data were calculated respectively using Higuchi's algorithm and Sano-Sawada's algorithm. We evaluated M/L length, total length of COP trajectory, fractal dimension, and the largest Lyapunov exponent during quiet and lateral-reach standing. A significant difference between young persons and elderly persons was indicated by Student's t-test.
RESULTS: The mean of the M/L length of COP trajectory for elderly persons during lateral-reach standing was significantly less than that of young persons (elderly=6.1 cm, young=12.1 cm, $p<0.001$). The mean of the total length of the COP trajectory for elderly persons during quiet standing was significantly larger than that of young persons (elderly= 31.6 cm, young=17.9 cm, $p<0.001$). In contrast, the mean of the total length of the COP trajectory for elderly persons during lateral-reach standing was significantly less than that of young persons (elderly=44.7 cm, young=83.5 cm, $p<0.001$). No significant difference was apparent in the fractal dimension and the largest Lyapunov exponent during quiet standing between elderly persons and young persons. However, the mean of the largest Lyapunov exponent of A/P and M/L COP trajectories for elderly persons during lateral-reach standing was significantly smaller than that of young persons (A/P COP, elderly=0.05, young=0.15, $p<0.001$; M/L COP, elderly=0.09, young=0.23, $p<0.05$).
CONCLUSIONS: Elderly persons shorten the M/L length of COP to gain stability during lateral-reach standing. In contrast, younger subjects lengthen the M/L length of COP to give up stability. These different balance strategies are revealed by the difference of the largest Lyapunov exponent value, which exhibits unpredictability of the COP trajectory. Indeed, elderly persons prefer to take a more predictable balance strategy than young persons during lateral-reach standing.

Rehabilitation Engineering

FUNCTIONAL ELECTRICAL THERAPY (FET) OF WALKING

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AIMS: Restoring of the walking in hemiplegic individuals is an important rehabilitation task. Current views favor intensive task related exercise as a method for promotion of recovery of the functioning. We designed a sensory-driven control for a four-channel electrical stimulation that can assist paretic leg in hemiplegic individuals. The stimulation pattern was controlled in a manner that mimicked the activation patterns (on/off, level of activation) typical for walking of healthy individuals.
METHODS: The four muscle groups selected for the FET of walking enhance the following functions: stance on the paretic leg (hip extension and ankle stiffness control), push-off on the paretic leg (ankle extensors, hip extensors), and swing of the paretic leg (dorsiflexion, hip flexion). The timings of the onset and end of stimulation of each of the four channels were controlled by a rule-based control. Rules for the control were established by using EMG data, kinematic data, and ground reaction forces measured in healthy individuals older than 60 years. We used Adapative Logic Networks - ALN for mapping of sensory states and EMG activities. The sensory information was reduced to the displacement from the vertical line of the shank (accelerometer), knee joint angle (accelerometers), and heel and toes ground reactions (force sensing resistors). The stimulation parameters were set to the following values: pulse rate f=50 Hz, pulse duration T= 300 μs, and stimulation intensity I = 10 - 45 mA. The monophasic charge compensated pulses were applied via surface electrodes. We assessed the efficacy of the system by assessing the following: 1) maximum walking speed and 2) symmetry index between paretic and non-paretic legs. The study included 8 hemiplegics who could stand, but could not walk for more than 10 meters with the rolling walker in good cognitive conditions. The assessment was done at the beginning and the day after consecutive five days 30-minute walking sessions.
RESULTS: The time to instrument a subject with the assistive system was 9±2 minutes (mean ± SD). All 8 patients learned how to walk with the electrical assistance during first few minutes of the first session. It was necessary to adjust the intensity of stimulation for every subject and every muscle group in order to secure non-painful; yet, effective stimulation that leads to muscle contraction. The use of the new control lead to the following changes in the maximum speed and symmetry index: the maximum walking speed increased from 0.21±0.17 m/s to 1.03±0.45 m/s, and the symmetry index decreased for about 28±11% to the 8±5%).
CONCLUSIONS: The four-channel stimulation that was controlled by a sensory driven rule-base control, which mimicked healthy muscle firing patterns, was an effective pattern for assisting of the walking in hemiplegic individuals. The improvement in the walking speed and symmetry were significant; thus, a randomized clinical trial of FET was initiated.

ESTIMATION OF HUMAN MUSCLE FORCE DYNAMIC RESPONSE USING A SHORT FEW SECONDS STIMULATION PROTOCOL

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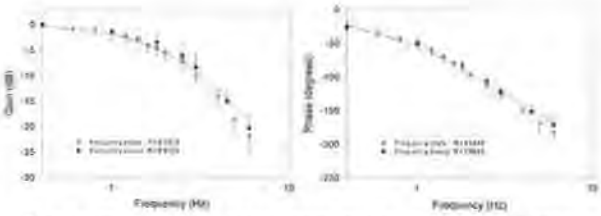
AIMS: To compare the dynamic responses of the tibialis anterior (TA) muscle-joint unit obtained after stimulation with:
a) 14 separated sinusoidal inputs (protocol duration: 40 min)
b) a short few seconds stimulation containing 7 sines (protocol duration: 5.18 s).
METHODS: Ten subjects (age: 23-50 years, 7 males, 3 females) volunteered for the study. The leg was fixed in an dynamometer in order to detect the torque generated during isometric contraction of the ankle flexors. The amplitude of a 30 Hz stimulation train administered at the TA motor point was varied sinusoidally, thus changing the number of the recruited motor units, and hence the tension at the tendon, in the same fashion. During 5.18 s the muscle was stimulated with a sequence of different sinusoidal frequencies (0.4, 1.0, 1.8, 2.5, 3.0, 4.5, 6.0 Hz; one period per frequency) termed as "sweep". After the sweep a sequence of 14 isolated frequencies (0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0 Hz), termed "steps", was administered. Each step lasted 5 s with a resting period of 3 minutes between one and the following; the total duration of the protocol was ~ 40 min.
For both protocols, a and b, the Bode plots for average (mean±SD) gain attenuation and phase shift, reporting the amplitude reduction and phase shift with respect to the input sine, were calculated.
RESULTS: In both protocols, from the Bode plots it was possible to model the force dynamic response of TA by a critically damped II order system with two real coincident poles + a pure time delay:
a) for the 14 steps: poles at 2.04 Hz and pure time delay of 15.6 ms;
b) for the sweep: poles at 2.19 Hz and pure time delay of 13.2 ms.



Bode plots for average (±SD) gains and phase shifts. The lines represent the theoretical II order system responses with double coincident poles + delay

CONCLUSIONS: The similarity of the steps and sweep transfer functions, obtained from the two stimulation protocols, suggests that it is possible to characterize the in-vivo mechanics of muscle-joint unit with a short (few seconds) sinusoidal stimulation. The frequency response could be used to design computerized controllers for rehabilitation devices and develop models of human movement for occupational and sports activities.

QUANTIFYING PROPRIOCEPTIVE REFLEXES AROUND THE WRIST IN PATIENTS WITH COMPLEX REGIONAL PAIN SYNDROME

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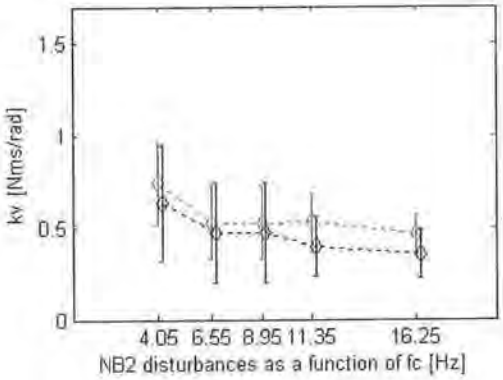
AIMS: Complex regional pain syndrome (CRPS) mainly affects the distal limbs and is characterized by sensory, autonomic and motor features. The pathophysiology of the motor dysfunctions seems to be impairment of interneuronal spinal circuits and the concomittant proprioceptive reflexes. The aim of this study is to investigate the modulation of proprioceptive reflexes around the wrist in patients suffering from CRPS.
METHODS: CRPS patients (n=16) and matched controls (n=16) had to hold the handle of a manipulator. The manipulator applied random torque disturbances, both in wrist flexion and extension direction, for 10s while the subject was instructed to minimize displacement of the handle. The angle of the handle, the torque at the handle and the surface EMGs in the m. flexor carpi radialis and m. extensor carpi radialis were recorded. From these, the joint admittance and reflexive impedance were obtained. By varying the bandwidth of the disturbances and the external damping, different reflex settings were provoked. In order to quantify the intrinsic and reflexive parameters, a model, including

wrist inertia, visco-elasticity of the (co-)contracted muscles and reflexive feedback was fitted onto the joint admittance and reflexive impedance.
RESULTS: Both CRPS patients and healthy subjects modulated proprioceptive reflexes around the wrist in response to changes in external damping and torque disturbance bandwidth; Especially the reflex velocity feedback gain (kv). However, no significant differences were found between CRPS-patients and controls (see figure).
CONCLUSIONS: Based on Schouten et al. (2003; Exp. Brain Res.), who measured proprioceptive reflex gains in the shoulder, a decreased ability to modulate of reflexes was expected for CRPS patients. The fact that no differences between the two groups were found in the wrist might be due to a different organisation of reflexes in the wrist in comparison to the shoulder. Other factors might be the large variety in the CRPS group and the relative 'healthy' subpopulation of the CRPS patients because of strict exclusion criteria.



Modulation of velocity feedback gains (kv) for CRPS (red) and controls (black) as a function of center frequency of the torque disturbance

ASSESSING THE RECOVERY OF POSTSTROKE PATIENTS USING ROBOT-AIDED TECHNIQUES

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AIMS: Recently a new sensory-motor rehabilitation technique based on the use of robot and mechatronic devices has been applied in stroke patients. This technique, by aiding traditional therapy, can improve the patient's motor performance, shorten the rehabilitation time and provide objective parameters for patient evaluation. Robotic systems for neurorehabilitation can be generally used to: a) provoke passive movements and/or trigger voluntary movements of the patient whose limb is physically attached to the rehabilitation device; b) record information about the motor performance (position, trajectory, interaction force/impedance) during active movements. This paper presents a robot devices for use in the rehabilitation of upper limb movements and reports the quantitative parameters obtained to characterize the rate of improvement thus allowing a precise monitoring of patient's motor recovery.
METHODS: A two degree of freedom (DoF) elbow-shoulder manipulator was designed using an admittance control strategy (Figure); if the patient could not move the handle the device completed the motor task. It was applied in the upper limb rehabilitation of two groups of post-stroke patients treated respectively within (recent) and after (chronic) the first six months of their cerebrovascular accident. The robot treatment was performed in addition to conventional physical therapy for 3-week (40 min., twice daily). All patients received physical therapy for 45 min. a day on the same days as robot treatment. Both groups were evaluated by means of standard clinical assessment scales and a new robot measured evaluation metrics that included an active movement index quantifying the patient's ability to execute the assigned motor task without robot assistance, the mean velocity and a movement accuracy index measuring the distance of the executed path from the theoretic one.
RESULTS: After treatment, both groups improved their motor deficit and disability. In recent group there was a significant change in the clinical scale values ($p<0.02$) and in the robot measured parameters ($p<0.01$). Chronic group showed a significant change in clinical scales ($p<0.01$), in strength ($p<0.05$) and in the robot measured parameters ($p<0.01$).
CONCLUSIONS: Our findings suggest that robot-aided neurorehabilitation may improve the motor outcome and disability of post-stroke patients. The new robot measured parameters may provide useful information about the course of treatment and its effectiveness at discharge. In addition they allow to speculate about the mechanisms of recovery and make it possible to precisely plan and, if necessary, modify the rehabilitation strategies. This technology, in combination with the diffusion of information and communication advances, opens the way to a successful application of robot-aided techniques directly in the patient's home.

2 DoF robot device for elbow- shoulder rehabilitation

A GAZE-DETECTION SYSTEM BASED ON A NOVEL NEURAL APPROACH

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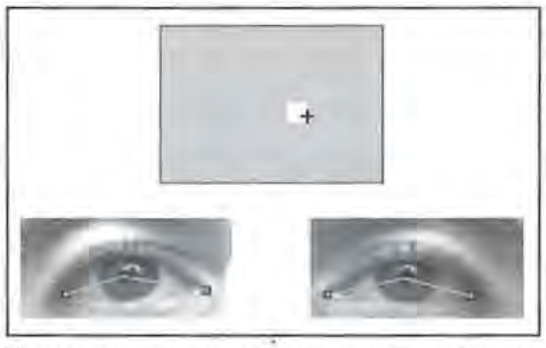
AIMS: A new method for gaze detection, based on a neural approach, is proposed. This work belongs to a wider research project concerning Human Computer Interfaces addressed to disable people. Many solutions to the problem of gaze detection could be found in literature, but just a few of them [1] propose non-wearable methods that use Artificial Neural Network (ANN). Others methods either require wearable devices or physical model of the eye. The primary aim of this study consists in developing a real time, self-calibrating Gaze Detection System. No wearable devices are needed, only one commercial camera and a personal computer. Accuracy of the method is evaluated with several tests.
METHODS: A specific eye-tracking algorithm has been developed in order to analyse the video sequence of a subject looking at the screen of a computer. The algorithm, based on Hough Transform and template matching, extracts a set of specific features of the eyes: the centre of the iris and the corners of each eyelid. Geometric relations between the eye features are then estimated. This set of parameters is then presented to an Artificial Neural Networks (ANN) in order to determine the position of the observed point on the screen (x,y coordinates). The proposed ANN is a multilayer Perceptron with 2 hidden layers (40 neurons each). Magnitudes and phases of the distance vectors between pupils and corners of the eyelids represent 8 of the 12 inputs. The remaining 4 inputs are the x and y coordinates of the external corners of the eyelids in the image plane reference system. The ANN provides only 2 outputs corresponding to x and y

coordinates of the observed point in the screen reference system. The Network is trained with a set of known input-output obtained by analysing the videos of a subject looking at a synthetic cursor that moves on known positions on the screen, and adjusted with an error-back-propagation algorithm.

RESULTS: Compared to the other methods found in literature [1], the input set and the complexity of the network are consistently reduced. Preliminary tests yielded good results. The accuracy has been calculated around 1.5 degrees (RMSE error). An eye-typing simulation showed a typing-rate of 30 letters per minute. A real time algorithm is about to be implemented.

CONCLUSIONS: A method to estimate gaze direction is proposed. The technique is based on a novel structured ANN. At the moment the subject is required to maintain the head still. The system will be upgraded with algorithms for a 3D estimation of the pose of the head so that movements of the head will be taken into account to broaden the application contexts and the number of functions.



The white square represents the cursor moving on the screen. The cross shows the reconstruct position of the point observed by the eyes

[1] S. Baluja, D. Pomerleau - "Non-intrusive gaze tracking using artificial neural networks" tech. report CMU-CS-94-102, Computer Science Department, Carnegie Mellon University, January, 1994.

MULTI-CHANNEL SURFACE EMG FOLLOWING NERVE-MUSCLE REINNERVATION OF THE PECTORALIS MUSCLES IN A SHOULDER DISARTICULATION AMPUTEE

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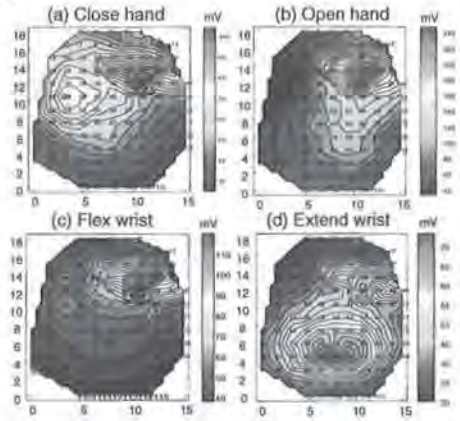
AIMS: Following surgical transfer of the musculocutaneous, median, radial and ulnar nerves to the pectoralis muscles, a bilateral shoulder disarticulation patient could simultaneously control two degrees-of-freedom of a myoelectric prosthesis using surface EMG signals from four reinnervated muscle sites [1]. It was hypothesized that further information contained in these signals could be used to control additional functions in a multifunction prosthetic arm. The purpose of this study was to record surface EMG activity above the reinnervated pectoralis muscle, using a high density multi-electrode grid, during a series of intended arm movements. This information provided an overview of the distribution of the surface EMG during 27 movements, enabling optimal EMG recording locations to be identified and was used to train a classifier to identify desired movements using EMG from several channels.

METHODS: An array of 115 active surface electrodes was placed in an approximately rectangular grid (15 mm spacing) above the reinnervated muscles. EMG signals were recorded in monopolar configuration and sampled at 2 kHz using a BioSemi Active II system (BioSemi, Amsterdam, Netherlands). EMG signals were recorded as the patient was asked to perform 27 intended arm or hand movements while following a simultaneous video demonstration of the movement. Each movement was repeated ten times. Following a 60 min rest period, the patient was asked to complete a separate test session consisting of 5 trials containing the 27 movements in random order. The experiment was repeated the following day. ECG artifact was removed off-line using a novel non-linear state space projection technique. EMG signals were then spatially filtered using bipolar and laplacian electrode configurations. Onset times of the EMG signals were identified and the RMS amplitude of the signals were estimated. Contour maps illustrating the distribution of the surface EMG signal were generated.

RESULTS: ECG artifact and additional periodic interference was successfully removed from the EMG signal. Distinct surface EMG distributions were evident for the different movement patterns. An example of data from four such movements is illustrated in Figure.

CONCLUSIONS: This experimental study represents the first stage in the development of a classification scheme for controlling multifunction prosthesis using surface EMG signals from reinnervated muscle tissue. The results presented suggest that with appropriate feature extraction and classification techniques it should be possible to increase the number of intended movements that can be reliably identified. Feature extraction and classification of the data is discussed in an accompanying paper [2].



Contour plots illustrating the mean RMS values of the monopolar surface EMG signals during four different contractions

[1] Kuiken et al., Prosthetics and Orthotics International 28, 245-253, 2004.
[2] Zhou, et al. 'Classification Of High Density Surface EMG Signals Developed By Targeted Muscle Reinnervation', ISEK 2006.

TARGETED REINNERVATION FOR IMPROVED PROSTHETIC FUNCTION

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AIMS: A novel method for the control of myoelectric upper limb prostheses has been developed. By transferring the residual nerves of amputees to spare muscles in or near the residual

limb, additional myoelectric control signals are made that allow the simultaneous control of multiple degrees-of-freedom (DOF) in a prosthesis. Since the nerve function correlates physiologically to the function it is controlling in the prosthesis, operation is more natural and thus easier than current control paradigms. Additionally, sensory reinnervation of skin can provide the sense of touch as if it were in the missing limb.

METHODS: The procedure has been successfully employed in several amputees. A patient with traumatic bilateral shoulder disarticulations (BSD) had four brachial plexus nerves transfers [1]: the residual nerves were identified; the neuromas cut off; the pectoralis muscles were denervated; the p. minor was transposed to the lateral chest wall; and the p. major was cut into 3 segments based on its neurovascular anatomy. The residual nerves were anastomosed to the pectoral nerve branches as they enter the muscle. Similarly, two nerve transfers were performed in a patient with a transhumeral (TH) amputation. The median nerve was transferred to the medial biceps and the distal radial nerve was transferred to the brachialis muscle.

RESULTS: In the BSD patient, four independent new myosites were created that allowed for simultaneous agonist-antagonist control of a powered elbow and hand. Testing with a box and blocks test showed a 250% improvement and a 26% increase in speed with a clothes pin moving test. Furthermore, the skin of the anterior chest was reinnervated with sensory fibers from the patient's hand and arm. Further work with a 6 motor arm allowed the patient to use myoelectric control of a humeral rotator using his latissimus dorsi and deltoid muscles and control of a powered shoulder and wrist with touch pads in his shoulder socket. He had a marked increase in functional work space and can simultaneously operate 3 DOF. Sensory reinnervation occurred in his chest skin. He has the sensations of graded pressure, hot, cold, vibration and pain as if it were in his missing arm.

Both nerve transfers were successful in the patient with the TH amputation. This patient was then also able to simultaneously use myoelectric control for a powered elbow and hand, and simultaneously control wrist rotation with shoulder motion for a total of three DOF. Objective testing showed tripling of speed with the block and box test and significant improvement with AMPS testing. Skin sensory reinnervation did not occur.

CONCLUSIONS: Target reinnervation has been demonstrated to improve the function of myoelectric arms by providing physiologically appropriate EMG data to operate a prosthesis. It is hoped that signal processing techniques will further improve performance and ease of use [1, 2]. Sensory reinnervation of skin is possible and could be an exciting portal allowing an amputee to feel what they touch with their prosthesis as if it was in their missing hand.

[1] Kuiken et al., Prosthetics and Orthotics International 28, 245-253, 2004.

[2] Lowery, et al. 'Multi-channel surface EMG following nerve-muscle reinnervation of the pectoralis muscles in a shoulder disarticulation amputee', ISEK 2006.

[3] Zhou, et al. 'Classification Of High Density Surface EMG Signals Developed By Targeted Muscle Reinnervation', ISEK 2006.

T14.P01
INVESTIGATION OF THE EFFECT OF WEAK PULSED MAGNETIC STIMULATION FOR MUSCLE FATIGUE

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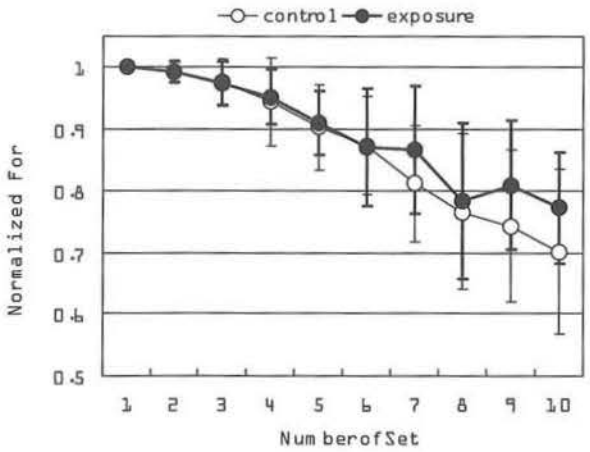
AIMS: Recently, the method of magnetic stimulation is being used as a new technique for nerve functional diagnosis as a replacement of electric stimulation in the clinical field. Althoug magnetic stimulation has a problem of improving focality, it has some advantages, noncontact, deeper and painless stimulation, to excite the muscle and nerve against electric stimulation. The authors have previously studied the effect of pulsed magnetic stimulation on recovery from fatigue. In this paper, the recovery effect of weak pulsed magnetic stimulation on peripheral muscle fatigue on the forearm was quantitatively examined.
METHODS: Subjects were seven healthy university students (average: 22.0 years, ranging: 21~24 years). All of them had no previous history of neurological illness and no special physical strength training. All subjects provided informed consent for the study. In this study, an object of measurement was flexor-digitorum-superficialis muscle and subject was lying on one's back during experiment. We made the muscle fatigue condition that was induced by grasping a hand dynamometer with 60% isometric maximum voluntary contraction during 40 seconds. This task was repeated 10 times at intervals of 180 seconds. Magnetic stimulation (Magstim model 200) with circular coil of 90 cm diameter (0.1 T) was performed 20 times at interval of 5 seconds between each set (exposure). We measured an exhibiting grip force, which was observed by strain gauge attached to the hand dynamometer, and integral electromyogram (iEMG). The recovery effect of weak pulsed magnetic stimulation for muscle fatigue was estimated by grip force and iEMG.
RESULTS: The average of normalized grip force at set 10 was 0.70 (±0.13) for the control and was 0.77 (±0.09) for the exposure. Figure shows the grip force with each set in the control and the exposure. The iEMG did not changed significantly at set 10. It can be considered that there is effect of induced current for the muscle fatigue. As a result, performing pulsed magnetic stimulation for muscle considering under the muscle fatigue condition had effect of an improvement in movement performance.
CONCLUSIONS: These results suggested that the muscle fatigue is mitigated by weak pulsed magnetic stimulation, which could not generate muscle contraction.



Normalized force with each set in control and exposure.

T14.P02
BASIC RESEARCH ON TRANSFEMORAL PROSTHESE USING SURFACE ELECTROMYOGRAPHY

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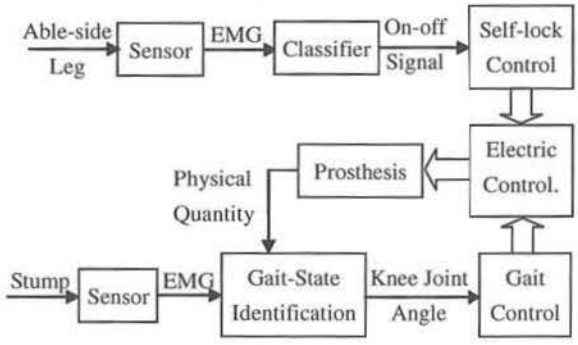
2) Research Institute of Prosthetics & Orthotics of the Ministry of Civil Affairs of P.R.China, Beijing, China

AIMS: For the optional control to the transfemoral amputee and natural gait, an ongoing investigation of prosthese model with myoelectrical control was presented. The most importante demand of lower limb prosthese is avoiding giving way and tumble, namely knee joint inflects suddenly when the prosthese is bearing. For example C-leg whit a sensor under the tiptoe. When the tiptoe use enough force, the self-lock knee joint will be open and the amputee can walk. In this research, the surface electromyography (EMG) extracted from the stump was used to be swith signal. And according to the different situation of stump, the surface EMG extracted from the able-side leg was use to control the prosthese.
METHODS: Five subjects were asked to walk with 40 steps per minute after quiet standing some seconds and stand 3 seconds quietly befor the end of testing. Surface EMG was recorded from rectus femoris at 2048 Hz.
The wavelet packet transformation (WPT) was used to extracted the feature vectors. And the support vector machine (SVM) to classify on-off signal and to predict the knee joint angle is also presented.
RESULTS: The SVM approach was compared with artificial neural network (ANN) method, and a superior classification on results were obtained.
Simulation results shows that surface EMG signal and knee joint angle have strong relation, and this arithmetic obtains preferable forecast result.
CONCLUSIONS: This myoelectric control system is described that offers exceptional performance with regard to two important aspects of controllability: the accuracy of movement selection, and the intuitiveness of actuating control. So it can satisfy the optional control and safety need.



The prosthese model whit myoelectrical control.

T14.P03
STUDY OF TERRAINS IDENTIFICATION BY EXTRACTING FEATURE VECTOR OF SEMGBASED ON LVQ NEURAL NETWORK

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AIMS: At present, artificial limb, including the intelligent prosthesis, is the "passive" prosthesis. People can't change the extension of the joint at will. Robot-Prosthesis is "active", it can

adjust artificial limb system according to the real environment. In this paper SEMG is the control source of the prosthesis for realizing the optional control.

METHODS: All the SEMG were collected from leg femoral quadriceps of right leg during steady-state locomotion at 1000 Hz. Simultaneously knee angle curve was recorded by 3D motion analysis. It must be preprocessed, i.e. denoised and segmented. The orthogonal Daubechies3 (Db3) Wavelet was selected as the base function. And the original signal decomposed into 3 levels and the energy of original signal is decomposed into 8 orthogonal frequency bands. At last, LVQ NN was used to classify the 3 kinds of terrains. In this paper, input layers have 28 neurons, output layers have 4 neurons, and competitive layers have 35 neurons. The 100 group data were selected as the training data from 200 group data, and the other 100 group were selected as data to be identified. So to reduce the workload, 8 group WP decomposition coefficients were transferred into 8 values with norm and standard deviation in the time domain again. At last each signal was represented by 8 values. Then the Willison amplitude (WAMP) and wave length (WL) were selected as the input of LVQ NN from 8 kinds of methods.

RESULTS: So the vector whose dimension is 2*24 is sent into the LVQ network. Output is 1*24 vector, [1...12....23....3], that notes three modes. Noting that 1 represents the locomotion on the Flat, 2 on the Slop and 3 on the Stair. Competition layer nerve number is 2, and the training epoch is 150. The sample recognition percent in the trained system achieves about 85%. The result was shown as Tab. 1.

CONCLUSIONS: This approach distinguished terrains based on WPT and LVQ network. Experimental results show that LVQ after effectively trained can be used to classify SEMG signal, and it has preferable performance. It is the critical problem to control the knee joint moment for improving the prosthesis and gait. But the algorithm, including preprocess, WT decomposition, and NN training, cost some time. It is not suitable for a real-time implementation. So it should be improved further. In addition, the EMG signal collected from identical stump is limited, and adopting sequence control of multilayer threshold value needs the sufferers train during a long time. In order to resolve these contradictions, the EMG signal should cooperate with other signals (such as switch fixed under tiptoe and heel) to realize multimode control.

Terrain	Classifier Form	Accuracy Rate (%)
Flat	Time/Fre Domain	52.4
	WPT	80.5
Slope	Time/Fre Domain	51.4
	WPT	81.5
Stair	Time/Fre Domain	60.5
	WPT	85.1

The recognize result.

T14.P04
CLASSIFICATION OF HIGH DENSITY SURFACE EMG SIGNALS DEVELOPED BY TARGETED MUSCLE REINNERVATION

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3) School of Electrical, Electronic and Mechanical Engineering, University College Dublin, Ireland; 4Department of Physical Medicine and Rehabilitation, Northwestern University, Chicago, IL, USA

AIMS: High density surface EMG signals were recorded from the pectoralis muscles of a shoulder disarticulation amputee following targeted muscle reinnervation, as the patient actuated a series of 27 different movements involving the amputated limb. The aim of this study is to apply pattern recognition techniques to the EMG that results from targeted reinnervation to determine how many different movements can be reliably classified. This work promises to dramatically improve the dexterity of prosthetic control for targeted reinnervation users.

METHODS: An array of 115 active surface electrodes was placed in an approximately rectangular grid above the reinnervated muscles [1]. The EMG signals were first processed to remove the baseline wandering and the ECG artifact. The onset and offset time of each contraction of a movement were determined based on a threshold detection scheme. The active segments above the threshold indicating muscle contraction were used for classification. Pattern recognition was performed on 256 ms analysis windows. Features were extracted from the EMG signals and then provided to the pattern classifier. A combination of sixth-order autoregressive (AR) features and the root mean square (RMS) of the signal were used as a feature set. The feature set was computed on each of the recorded channels, concatenated into a single feature vector, and provided to a linear discriminate analysis (LDA) classifier. Disjoint analysis windows from the first half of the active data were used to train the LDA classifier. Analysis windows from the other half of the active data were used as a test set to evaluate the classifier's accuracy. The performance of monopolar, single differential, double differential and laplacian configurations was investigated, as well as the effect of various spatial filter orientations and inter-electrode distances. In addition, a means of reducing the number of recording channels was developed, while keeping a similar classification performance.

RESULTS: An overall accuracy of 91% was achieved in classification of the involved movements using all the monopolar channels of the surface EMG recording. The classification performance varied with different data configurations, with better performance being obtained when configurations other than monopolar recording were used. For example, with a double differential configuration, the overall classification accuracy reached as high as 97%. We also found that it was possible to achieve satisfactory classification performance (up to 90% overall accuracy) when a very small number (as low as 10) of EMG channels were appropriately chosen for classification.

CONCLUSIONS: This study extended pattern recognition techniques to the new EMG sources developed by targeted muscle reinnervaton. The classification results suggest the potential and offer guidance for further improvement of the prosthetic control in laboratory as well as clinical environments.

[1] Lowery, et al. "Multi-channel surface EMG following nerve-muscle reinnervation of the pectoralis muscles in a shoulder disarticulation amputee," ISEK 2006.

T14.P05
ANALYTICAL MODELIZATION OF PLANAR MONOARTICULAR MOVEMENTS FOR THE DETERMINATION OF THE RESISTIVE COEFFICIENT IN MUSCLE STRENGTH EXERCISE

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INTRODUCTION: Muscle strength training is one of the most common therapies in rehabilitation programs. Usually, when prescribing a strengthening exercise only a few variables are indicated, such as joint angular excursion, resistive load, isotonic/isometric/isokinetic exercise, eccentric/concentric/isometric exercise, closed/open kinetic chain exercise. However, training devices cannot usually fit to the anthropometric characteristics of each subject and to the different execution modalities so that the proportion of the resistive load eventually applied to synergist and stabylizing muscles cannot be predicted. It would be useful for a correct rehabilitation program planning to understand which variables - related to the subject, the training device and the execution modality - can influence the eventual muscle load during movement. The purpose of this study is to create an analytical model for planar monoarticular movements against a resistive load applied to the end-effector (E-E) through a pulley system.

METHODS: The E-E trajectories are circular in planar

monoarticular movements. To determine the forces that are required to produce the movement (inverse dynamics problem), it is necessary to calculate the resistive coefficient k, that indicates the intensity of the tangential component of the force applied to the E-E. According to the kinematic geometry and using the Denavit-Hartenberg convention we determined a model accounting for the tangential component of the resistive force. According to the Newton-Eulero theory (industrial robotics) we determined another model accounting also for the other forces relative to rigid body mechanics (frictional, inertial and gravitational forces). Modelizations were developed in MATLAB (The MatWorks Inc., Natik MA, USA) to obtain the resisitive coefficient k as a function of the considered variables and to compare the different modelizations. An experimental investigation into the relationship between muscle activation and joint load was performed with an ELITE system (BTS S.p.a., Milano) by evaluating the muscle strength exercise execution in different modalities.

RESULTS: The resistive coefficient k is a function of the initial length λ_0 of the cord, of the initial angle γ_0 between the pulley and the joint distal segment, of the length **a** of the the joint distal segment and of the instantaneous joint angular excursion ϑ. The variability of k equi-levels curves displayed at the "*Litmus paper*" (Figure 1) (relative to different couples of γ_0 and ϑ values) depends on the ratio between λ_0 and **a** values. Muscular activity evaluated by sEMG showed different patterns according to the different execution modalities.

DISCUSSION: The introduced analytical model allows to identify the variables influencing the intensity of the resistive forces during the movement execution and to accurately determine their values according to the rehabilitation criteria. For example, if a clinical condition requires to execute only a partial range of motion, it would be possible to maximize the resistive force in order to enhance muscle strength by varying λ_0 and γ_0 (Figure 1). Moreover, when the time function of joint angle $\vartheta(t)$ is assigned, peak values of joint load during movement would be kept under a given threshold by mutually adjusting external loads and speed movement. These results underline the importance of disposing of training devices that allow to indicate specific values for each variable. The existence of different muscular patterns depending on different morphology of the k coefficient curves will make it possible to plan rehabilitation and training programs aimed at achieving specific objectives.

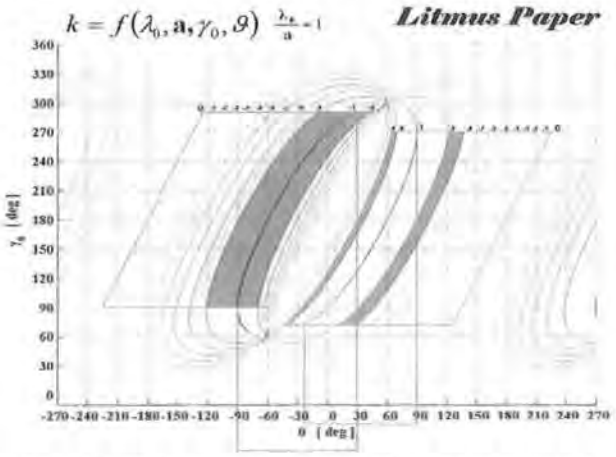

Figure 1. k equi-level curves as function of γ_0 and instantaneous angular displacement ϑ is reported, given a $\lambda_0/\mathbf{a}$ ratio value.

T14.P06
FIRST EXPERIENCE OF MeCFES FOR ASSISTING TETRAPARETIC HANDS IN ACTIVITIES OF DAILY LIVING

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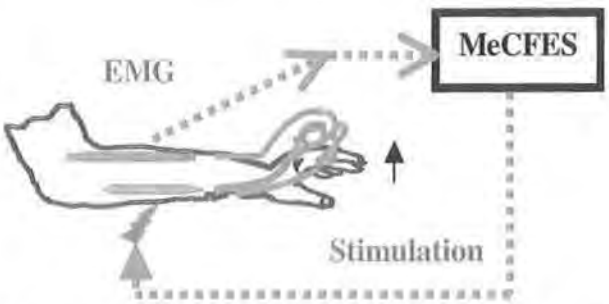
AIMS: The purpose of this project is to test a non invasive method for improving hand function in people having sustained a cervical spinal cord lesion and to evaluate its use for performing activities of daily living (ADL).

METHODS: The myoelectric signal (MES) from the wrist extensors is used to control stimulation of the finger flexors using a Myoelectrically Controlled Functional Electrical Stimulation (MeCFES) system. A convenience sample of people with sustained tetraplegia, having good wrist extension but weak finger flexion when using the tenodesis grip, are enrolled in this study. Previous studies concluded that one channel of MES and stimulation can augment the force of the tenodesis grip and increase score of hand function test in five subjects [Thorsen et. al.]. In this part of the study focus is on the usefulness for identified ADL. Subjects re-admitted at the spinal unit is offered to test the device for ADL and the subjects are reporting for which tasks they are using the device and for how long and if it results in increased autonomy.

RESULTS: The first subject has used the MeCFES for a 3 weeks on his non dominant hand. Despite being the non dominant hand it enables him to do more ADL tasks, such as handling bottles and adhesive tape. Recently he has acquired ability to apply the system autonomously.

The MeCFES enabling a person, with a C5/6 lesion, to hold and shake a full bottle.



EMG from wrist extension is controlling stimulation of finger flexors to improve the tenodesis grip.

Further results from hand function tests with and without the device, before and after the test period, together with the subjects opinion about the usefulness of the system, will be presented.
CONCLUSIONS: Previous studies have shown that the grasping of a number of everyday objects can be improved by the system and trials have commenced to test daily use. The results will show defects and advantages of the system.

Thorsen, R. et. al "FES Reinforced Tenodesis Effect Controlled by Myoelectric Activity from Wrist Extensors" J. Rehab. Res. and Dev., In Press 2006.

T14.P07
A NEW CLINICAL TOOL FOR THE ASSESSMENT OF THE HAND FUNCTIONALITY

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Severe peripheral neuropathies, arthrosis, tendon inflammations, wrong working habits, repeated use of working devices, elderly pathologies can lead to severe damages to the hand functionality. In order to investigate the recovery of the hand function a quantitative assessment should be performed. We designed a clinical tool with an associated test for a wide ranging quantitative assessment of the hand functional recovery. The clinical tool is based on an instrumental kit for the assessment of the hand-finger forces and kinematics. In order to perform an assessment of the hand-finger forces a special set of keyboards has been designed and constructed. This instrumentation allows the assessment of the maximum force the fingers can exert under isometric conditions. More specifically, two type of keyboards have been realised. The first permits the measurement of the force each finger exerts against the corresponding instrumented key; the other measures the force the thumb exerts while grasping a mouse-like metallic support. In order to perform a kinematic assessment of the hand-finger a commercial device (Human Glove by Humanware s.r.l., Pisa, Italy) which contains 20 Hall-effect angular displacement sensors. The test was designed in order to investigate both the recovery of the functionality and for associating to the subjective medical evaluation precious information ready for a datamining. The dynamic test associated to the keyboards was based on a dedicated software which allows the subject to pursue/follow pre-established force profiles . The kinematic test associated to the glove was based on Virtual Reality software procedures permitting also a quantitative analysis. It permitted to investigate both the hand fingers during kinematics and during tasks reproducing different real life constraints (for example the displacements of objects with different shape and dimensions) (Figure 1).

Figure 1(a). The complete equipment for the hand-fingers kinematic assessment, with the software for 3D virtual reality image displaying.

Figure 1(b). The glove with 20 hall-sensors.

The methodology conducted on 5 healthy subjects was proved to be efficacy, permitting an accuracy of 10^{-1} degs and 10^{-2} N respectively under the kinematic and dynamic trials.

T14.P08
FES ROWING AFTER SPINAL CORD INJURY

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AIMS: Functional electrical stimulation (FES) assisted indoor rowing is a form of exercise for adults with spinal cord injury which involves the whole body, and is effective in developing cardiovascular fitness and muscle mass in all extremities. Recently FES rowers have competed against able-bodied athletes in a national competition in which indoor rowers race over the Olympic 2 km distance. Here we describe the adaptations to a Concept 2 rowing machine for FES rowing use. We also present our results achieved to date, indicating the differences between normal and FES rowing techniques and the computer control of the stimulus.
METHODS: Standard Concept 2 indoor rowing machines were modified for FES assisted rowing. The seating system has a high back with adjustable backrests and seat belt for stabilising the trunk. A telescopic mechanism with calf cuffs constrains the legs to move only in the sagittal plane, and a footplate stabilises the feet. Two extra rollers were added to the modified seat carriage to accomodate the larger than normal force actions transmitted to the I-beam track. Spring loaded end stops limit the movement of the seat on the track thus limiting flexion/extension of the knees. The seat is equipped with a brake to facilitate transfer and enable arms only rowing. Stimulation is applied through surface electrodes acting on the quadriceps muscles during the drive phase of rowing. A combination of direct stimulation of the hamstrings, gastrocnemius and pretibial muscles is used together with reflex flexion (elicited typically by stimulating the common peroneal nerve) at the hip and knee with dorsiflexion at the ankle during the recovery phase. The latter arrangement is arranged to counteract any hip extension and ankle plantarflexion produced by the direct stimulation of the bi-articular muscles of the hamstrings and gastrocnemius. In a simple arrangement, the drive phase is initiated, at the catch position, by pressing a button switch located on the handle. The stimulus intensity is adjusted throughout the drive phase by the computer based on the position of the seat. The recovery phase is initiated by releasing the button switch. The stimulus (bi-phasic) parameters are adjusted between frequency 10-100 Hz, up to 150 mA with individual channel control of pulsewidth up to 500 µs.
RESULTS: Volunteers quickly acquired the technique of FES

rowing after a few sessions. The technique is somewhat different from that used by able-bodied rowers. In FES rowing, the stimulation needs to be controlled to maximise power output while avoiding excessive fatigue, and so that the knees do not buckle under the pull from the arms.

CONCLUSIONS: FES assisted indoor rowing has been demonstrated as an effective form of exercise. Paraplegics can now work out at relatively high levels, up to 3 litres of oxgen per minute over 30 minute sessions. The system has also been used competively in the British Indoor Rowing Championships 2004 and 2005 (see www.FESrowing.org). Further improvements include tuning computer control of the stimulation and adding additional extensors during the drive phase.

The FES indoor rowing system in use.

T14.P09
DEVELOPMENT OF COOPERATIVE WORK SYSTEM DRIVEN BY ULTRASONIC MOTOR USING ELECTROMYOGRAPHIC SIGNALS

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2) CREST JST, Japan

AIMS: Generally speaking, a robot means mostly industrial robot, but new type humanoid robot such as assistant and rehabilitation robot for the old and the patient has received much attention. In this case, an impeadance of such humanoid robots should be matched with that of human's arm in order to carry out cooperative works harmoniously. Therefore, the aim of this paper is to develop the system that adjust the impedance of a robot driven by ultrasonic motor (USM) for impedance match with human's arm in cooperative works. The impedance of human's arm is calculated by mathematical musculoskeletal system model (MMSM).

METHODS: The proposed cooperative robot behaves flexibly like as human. Because the USM has many good characteristics similar to muscle. To control torque of USM, a lot of methods such as adujsting the frequency, amplitude and phase-difference of two sinusoidal voltage waveforms power parameters have been proposed. Among these methods, we controled the impedance of the robot using USM's Phase difference determined by changing a differential coefficient K in the PD control system. On the other hand, to estimate time-varying stiffness of subject's arm on the sagittal plane, we used MMSM method. The rectified, filtered and normalized EMG signals of the subject were used as motor command 'u' of MMSM. We can estimate a time-varying joint torques and stiffness simultaneously using MMSM method. Estimated joint torque agrees well with the real joint torque. In this study, we performed two types of tests, one is to adjust differential coefficient K by manual operation and the other is to apply the estimated imedance of a human's arm to the robot through close loop cycle.

RESULTS: Figure shows the system that impedance of human is applied to the robot arm while he shake hands with the robot. The robot could behave like as human with elasticity that could be changed according to circumstances. And subjects could have a feeling like as handshaking with another person. In this case, both sampling times of processing EMG signals and controlling USM are 1[Khz]. The measured EMG signals was quantized into an integer from 1 to 10 as impedance of human. When subjects put out more force, the a differential coefficient K would be increased. For example, if the K is 1, then the phase difference would be 30 degree at angular displacement of 20 degree. However, if the K is 3, the phase difference would be 60 degree even at the same angular displacement. Therefore, the subject could feel more strenth force at the same angular displacement. Because the output torque of USM becomes larger in proportion to the phase difference.

CONCLUSIONS: The proposed system is very available and effective for the cooperative works. The subject could execute cooperative work without feeling of rejection. Therefore, the proposed cooperative system could be used for assistant and rehabilitation robot.

Cooperative work system driven by ultrasonic motor using EMG signals.

Sensor and Wearable Ambulatory Technology and applications

MONITORING MOBILITY ASSISTIVE DEVICE USE IN PATIENTS AFTER STROKE

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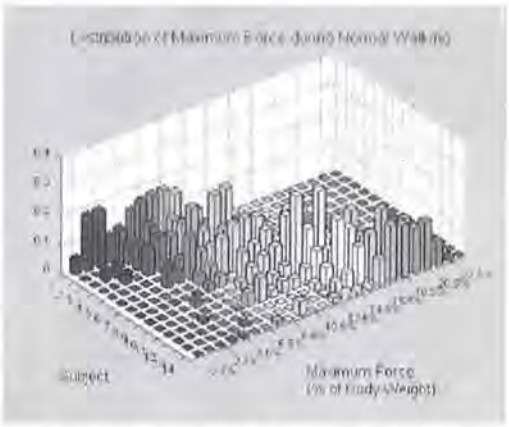
AIMS: Mobility assistive devices (MAD) such as canes can improve mobility and allow independence in the performance of mobility-related tasks. The use of MAD is often prescribed for stroke survivors. Despite their acknowledged qualities, MAD in real life conditions are typically underutilized, misused and abandoned. Ecologically sound, evidence based outcome measures need to be developed so as to capture the inherent complexities behind real life use of MAD and identify markers and mitigators of a successful integration of MAD into the daily activities of stroke survivors. In this study, we used accelerometers, gyroscopes, and a load cell to identify the task a patient was performing and examine the use of the cane in the context of the task.
METHODS: Fourteen stroke patients who used a mobility assitive device were recruited in the study. Three-axis accelerometers were attached to the wrists and ankles. A cane outfitted with a load cell was used. Each subject performed 10 to 30 repetitions of ten different tasks, including normal walking, walking up and down a ramp, walking up and down stairs, walking on an uneven surface, walking over an object, pivoting, and opening a door. Data segments of 5.5 s were taken from the recordings of each task. Features were extracted and then used to train an artificial neural network to identify the ten tasks. Next features relating to the use of the cane were estimated, i.e. the maximum weight applied to the cane and the duration for which the force was applied to the cane within each ambulatory cycle.
RESULTS: The performance of the neural network in identifying tasks was evaluated by deriving receiver operating characteristics for each subject. For a sensitivity of 95%, the specificity varied from 96% up to 100%. The median sensitivity for each task ranged from 93% to 100% and the median specificity varied between 98% and 100%. The variation in the maximum weight applied to the cane among tasks was large. Figure shows the the maximum force applied to the cane during normal walking.



Maximum Force on Cane during Normal Walking

CONCLUSIONS: The results demonstrate the potential of this system to be utilized for evaluating the use of a cane by patients after stroke. The classifier was able to identify tasks with a sensitivity and specificity of more than 95%. The variation of cane features across different tasks shows the importance of evaluating the use of the cane in the context of the task being performed. The distributions of features relating to cane use across subjects shows the ability of our system to detect variations in cane use and its potential to evaluate and diagnose problems in the use of the cane.

WEARABLE FUNCTIONAL STATUS MONITOR FOR PATIENTS WITH STROKE

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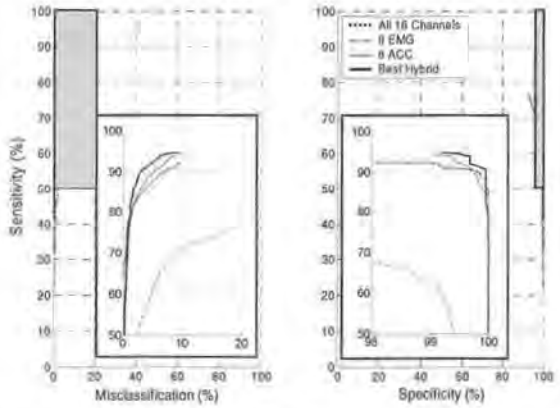
AIMS: The goal of this work is to develop a wearable functional status monitor for patients with stroke. The portable system will utilize a limited number of sensors that detect both surface electromyographic (sEMG) and accelerometer (ACC) signals while the patient is in their home or other remote location. The system will process these signals for feature extraction and automatically classify the activities based on artificial intelligence algorithms. The goal is to achieve 90% accuracy for specific activities of daily living that are indicative of functional independence, with no more than 4 sensors. This paper focuses on algorithm development and the relationship between classification accuracy and the combination/number of sensors utilized.
METHODS: Eleven subjects with a history of stroke consented to participate in this study (37-67 years old; 6 females, 5 males; independent ambulators with minimal/moderate hemiparesis). Data were collected in the laboratory from 8 pairs of sEMG and ACC sensors located on trunk and bilateral upper and lower extremities. Recordings were made using a script where subjects carried out 11 functional tasks representative of ambulation, feeding, grooming, dressing, and toileting activity skills ("ID Tasks"). Eleven "Non-ID tasks" were included to test the ability of the algorithms to differentiate among tasks that appear similar in movement to the Identification tasks.
RESULTS: We were able to achieve the classification accuracy set forth in our aims through a combination of feature extraction algorithms, a multilayer feed forward neural network (ANN), and an adaptive neuro-fuzzy inference system. The architecture for the ANN consisted of an input layer with 2 hidden layers (44 and 22 neurons each) and an output layer with 11 outputs. Half of the ANN results were used as a training set for generating fuzzy rules to "accept" a specific Identification Task. Performance of the system is summarized in Figure where a 4-sensor "Best Hybrid" combination of EMG and ACC signals achieved identification of the ID tasks with approximately 90% or better sensitivity and specificity and misclassifications of the non-ID tasks (%misclassification) of less than 10%.



Plots of sensitivity vs. misclassification (L) and sensitivity vs. specificity (R) for 8 EMG and 8 ACC sensors in patients (N=11) with stroke. The classifications are for 11 functional activities (ID-Tasks) described in the text, and 11 "Non-ID" tasks. "Best Hybrid" refers to the best 4-sensor result for hybrid sensors that combine EMG and ACC data. The insert is an enlargement of the shaded area.

CONCLUSIONS: Accurate automatic classification of Activities of Daily Living tasks is possible through a minimal set of EMG and ACC hybrid sensors and artificial intelligence algorithms. Studies are underway to achieve similar classification accuracies under more "real-world" conditions where superposition of task occurences must be resolved.

This project was funded by NIDRR Field-Initiated Project Award # 133G020108

A NOVEL INTEGRATED SYSTEM FOR PATIENT HOME MONITORING

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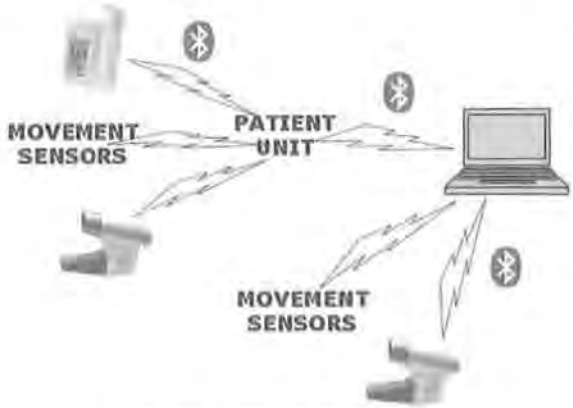
AIMS: The aim of this work is to develop an integrated system of software and hardware for the home monitoring the elderly in his/her home. Particular attention was given to instrumentation cost and to patient's comfort during sensor design and measurement layout. Moreover, the possibility of integrating commercial wireless instruments and create intelligent sensors is also evaluated.
METHODS: The hardware system consists in a set of wireless sensors and a patient unit integrating Bluetooth technology. The wireless movement sensors connectable to the system are accelerometers (Analog Device ADXL203 and Freescale MMA7260Q), ECG, sEMG, electrogoniometers and basographs, intelligent actigraphs. The system can also be connected to other commercial Bluetooth instruments. Intelligent actigraphs developed in this work, are wireless sensors that can elaborate motor activity data on board. This sensors are highly configurable and can execute all the main DSP function in real time. Sensors can be connected directly to a commercial PC Bluetooth receiver or to the patient unit that can be used as a gateway or as a data logger. Recorded data is collected and stored by a computer application, which can configure wirelessly sensors and patient unit and show data on a graph in real-time. The firmware loaded on the sensors, written in C language, is highly configurable. It is possible to change transmit bit rate, device name and PIN directly from computer application.



Possible system configuration

RESULTS: Tests conducted on sensors showed an operating range in open space of about 20 m range for the class 2 Bluetooth module, and 100 m range for the class 1 Bluetooth module. The number of maximum devices connectable to PC or patient unit is limited to 7 by Bluetooth standard. Data can be transmitted at a maximum bit rate of 115200 baud/s. Sensors can operate at a selectable sampling rate of 1440 samples/s or 2880 samples/s during low resolution mode (8 bits), and 720 samples/s or 1440 samples/s during high resolution mode (10 bits). Sensors have power consumption during transmit mode of about 100 mA when using class 1 Bluetooth modules and about 80 mA when using class 2 Bluetooth modules. The cost for producing one single sensor unit ranges from 70 to 90 USD, the Bluetooth module being the most expensive part.

CONCLUSIONS: The transmit data rate is highly compatible with the bandwidth needed by motion analysis sensors. Sensors have proven to be reliable and suitable for the proposed application. The importance of intelligent sensors which can elaborate data on board appeared to be really promising in terms of efficiency and power consumption: most part of power consumption is due to Bluetooth communication and thus, limiting data to transmit is the best way to achieve low power consumption.

INTRODUCTION OF LOCATION FREE MOTION ANALYSIS TOOLS FOR PATIENT TRAINING

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2) Relion
4) Xsens MT
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AIMS: This paper introduces a new tool for enhancing the communication between patient and therapist for training and coaching in behavior related aspecifc low back pain.
This effort is part of an ongoing effort of researching location independent motion analysis tools for rehabilitation, sports and ergonomics by the Dutch FreeMotion consortium and builds on Exo-Zorg and AmbuLab projects.
METHODS: Great care was taken to minimize patient and clinician burdon. A leg- and armless prototype suit was developed for easy mounting a motion sensor system on the patient. Sensors, cables and wireless control unit were fully integrated in the suit (removable). A quick single posture segment calibration procedure was developed, automatically performed in the start of (optionally each) recording. Only assumption person assumes neutral uprght posture facing any global direction.
A tool was developed, which records, processes and visualizes in real time 3D motion of upto 7 body segments plus synchronized video of a remore controlled webcam. Motion is visualized in a full body avatar-skeleton in 3 simultaneous views.
Additional graphics show fase plots and ranges of motion of a chosen signal history. Protocol performance was automated and comments can be added at any time. For off-line viewing and discusiing a time cursor controlled viewer was realized. (Semi-automatic) cycle handling is included. A dedicated examination room cabinet is being developed with large monitor on retractable arm.
RESULTS: Location independent accurate motion analysis was already possible. Sensor casing absolute orientation accuracy is within 2 degrees. The single posture segment calibration functions independent of direction faced by the subject and is depending on assumed posture. Repeatability of assumed posture is high in frontal and transverse plane and less reproducible in sagital plane.

Coach viewer GUI example: Comments, information on ROM, realtime video + 3D avatar skeleton and kinematics faseplot

CONCLUSIONS: A practical tool for visualising/parameterizing human motion for a specific clinical application was realized using affordable hardware. An explorative clinical study is set up to

test added value of tool for coaching. The availability of the practical tool triggered ideas from clinicians for several other apparaent viable practical clinical applications. Caution is required in interpreting angular information in too much detail. More sophisticated helical axes segment calibration procedures may be required (available and validated). As in any state of the art motion analysis method central issue will now be accuracy and reliability issues, which stresses the need for well defined patient specific calibration procedures and motion artefact handling.

Baten C, de Vries W, Smeding J, van Staveren G, Wassink R. Ambulatory inertial Motion analysis. The 12th annual ESMAC meeting. Marseille, France: 2003.
Baten CTM, Luinge HJ, Moerkerk H v., Estimating body segment orientation applying inertial sensing. Proceedings of the Sixth International Symposium on the 3-D analysis of Human Movement. Cape Town, South Africa: 2000.

WIRELESS BIO-FEEDBACK SYSTEM FOR BALANCE CONTROL

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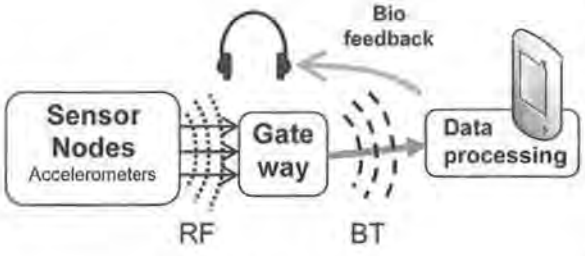
AIMS: The present study presents a Biofeedback Wireless Wearable System (Bio-WWS) able to track human movements and to provide audio biofeedback restitution for improvement of balance, developed using a Wireless Body Area Network [1] based on inertial sensor nodes. Bio-WWS can be utilized for rehabilitation after a damage of the motor system, as an aid in case of sensory deficits or for training in sports. Bio-WWS aims to respond to the need of easy accessibility (in terms of unobtrusiveness, portability and low-cost) of biofeedback systems for rehabilitation, typically still cumbersome and expensive, mainly for ambulatory use with the need of specific expertise, and wired.
METHODS: Bio-WWS configuration includes 3 wireless sensor nodes based on tri-axial MEMS accelerometers (LIS3L02DQ, STMicroelectronics), placed on the trunk and on the upper and lower leg. The sensor nodes communicated via RF, using a transceiver working at 868 MHz, with the gateway-node, which performs a pre-processing of the data and forwards them to a palmtop computer over a Bluetooth link (BT). The palmtop (an HP iPAQ 5550) processes the accelerometric data in order to resolve the human's posture condition and to provide, through a stereo headset, the adequate biofeedback to help the users to maintain their trunk acceleration within the physiological range. To this aim, the audio biofeedback is generated by an algorithm already validated (see [2] for details), customized to correct posture in quiet stance (condition detected by the leg's accelerometers) and based on the planar accelerations of the trunk (updated every 50 ms) along the forward-backward and left-right directions. The forward-backward acceleration is coded by frequency and amplitude modulation of the sound; the left-right acceleration is coded by left-right balance modulation of the sound.



BIO-WWW's architecture

RESULTS: The validation of Bio-WWS was performed comparing amount of postural sway, by means of a force-platform, in different sensory-altered conditions, with and without activation of Bio-WWS. Preliminary results confirm the usefulness of the audio biofeedback algorithm to inform the user about the amount and direction of sway in quiet stance, allowing the proper correction of posture. The wireless design of the system and the low-power consumption provide a high comfort level to the user and long-term usability.
CONCLUSIONS: The implementation of the audio biofeedback presented in this study allows the availability of postural rehabilitation at any time in any place without the need of expert assistance or ambulatory infrastructure. Furthermore, high flexibility of Bio-WWS's architecture consents to easily optimize existing biofeedback applications and to develop new applications in more than one context, through the integration of many different sensor nodes and algorithms in a Wireless Body Area Network.

[1] E. Farella et al., "Design and Implementation of WiMoCA Node for a Body Area Wireless Sensor Network", IEEE Proc. Int. Conf. Sensor Networks, 2005.
[2] L. Chiari et al., "Audio-Biofeedback for Balance Improvement: An Accelerometry-Based System", IEEE Trans. Biomed. Eng., 2005.

UPPER TRAPEZIUS EMG ACTIVITY DURING SEATED COMPUTER WORK AND IN UPRIGHT POSTURES

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2) Human Movement Sciences Programme Norwegian University of Science and Technology

AIMS: Prolonged seated computer work is recognized as a risk factor for shoulder pain. Ergonomic guidelines recommend variation between body postures (sit, stand, walk) to counter the problem. The study aimed to explore the extent of variation in trapezius EMG activity patterns between seated (presumed risk situation) and upright postures (periods with presumed pain relief) in a vocational setting with computer work. This may provide clues to putative pain-relieving muscle activity patterns.
METHODS: Twenty-six female computer operators (mean age 44±11 yrs) participated in the study. Bilateral upper trapezius surface EMG activity and thigh angle were recorded in parallel throughout the workday (Physiometer PHY-400, Premed A/S, Norway). Thigh angle was used to differentiate between body postures. The EMG signal was calibrated by the EMG response at maximal voluntary contraction (% EMG_{max}). EMG activity was quantified by median EMG level (% EMG_{max}), rest time (duration of EMG activity <0.5% EMG_{max}; % of recording period), burst time (duration of EMG activity >2% EMG_{max}; % of recording period) and burst rate (number of bursts >2% EMG_{max}; per s). Shoulder pain and work stress was scored on visual analogue scale (VAS) on hourly basis throughout the workday.
RESULTS: Shoulder pain and stress augmented during the workday, confirming that the occupational setting represented a risk of pain development. Time (% of workday) with a seated posture (80.3±9.1%) was considerable larger than time spent standing (11.4±6.6%) or walking (5.4±2.8%). All unitary comparisons of trapezius activity between body postures where significant for median EMG level, rest time and burst time. Burst rate was significantly higher during walking than sitting and standing. Median EMG level was very low during the presumed risk situation, with intermediate activity during standing, and highest activity during walking. A significant difference in EMG activity between the dominant and non-dominant trapezius was found for all EMG variables during seated work but not in upright postures.
CONCLUSIONS: The present findings, together with existing guidelines for healthy work, suggest that intermittent periods with increased muscle activity may reduce shoulder pain in sedentary work. A possible physiological mechanism is that increased burst rate during walking induce increased substitution

of low-threshold motor units; suggested to protect against overexertion of low-threshold motor units in sustained low-level contractions.

	Sitting	Standing	Walking
Median EMG			
Dom.	1.8 (1.0-2.0)	3.0 (2.1-3.6)	3.9 (2.7-5.7)
Non-dom.	0.9 (0.9-1.2)	2.5 (1.4-3.5)	3.4 (2.5-4.7)
p=	0.01	ns	ns
Rest time			
Dom.	29 (24-38)	13 (7.9-22)	4.8 (2.1 7.0)
Non-dom.	45 (32-49)	17 (8.6-29)	4.5 (1.6-6.3)
p=	0.05	ns	ns
Burst time			
Dom.	47 (39-50)	61 (51-70)	75 (62-84)
Non-dom.	33 (27-39)	58 (42-67)	71 (60-88)
p=	0.005	ns	ns
Burst rate			
Dom.	0.25 (0.22-0.29)	0.27 (0.23-0.31)	0.54 (0.44-0.70)
Non-dom.	0.20 (0.16-0.24)	0.28 (0.23-0.31)	0.58 (0.41-0.82)
p=	0.004	ns	ns

Trapezius EMG activity
(values are median with 95% CI in parentheses)

A SMART TEXTILE T-SHIRT FOR LONG TERM MONITORING OF ECG AND EMG SIGNALS

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1) National Institute for Working Life, Göteborg, Sweden
2) Chalmers University of Technology, Göteborg, Sweden
3) University College of Borås, Borås, Sweden
4) Norrlands University Hospital, Umeå, Sweden
5)Umeå University, Umeå, Sweden

AIMS: *Smart textiles* is a generic term for textile materials and products that interacts with the environment and users. Combined with wearable electronic devices, smart textiles can facilitate long term ambulatory monitoring on a 24-7 basis. One big advantage with sensors integrated in clothing is that subjects may don and doff the sensors themselves, thereby facilitating direct measurements of e.g. heart and muscle activity outside the laboratory. However, this way to easy apply ECG- or EMG-electrodes has two disadvantages. Firstly, as the electrodes are not affixed directly to the skin, the recording position may change slightly or an electrode may even lose contact during the recordings. Secondly, using "dry", non-gelled, textile electrodes may result in poorer recording conditions than when using conventional electrodes.
As a step towards improving the usefulness of textile-based electrodes for recording of electrophysiological signals, this study aims at testing various methods to cope with the above difficulties inherent in these devices. A specific goal was to detect ECG signal good enough to monitor heart rate and heart rate variability using smart textiles.
METHODS: As monitoring of heart activity is relatively insensitive to the position of the sensors, the smart textile approach is better suited to ECG than EMG recordings. Further, the ECG signal can be recorded from many positions of the trunk allowing multiple channel recordings to contribute the wanted information, and thereby reducing the risk of data loss due to problems in a single channel. A multi-channel approach was chosen to cope with disturbed or even missing ECG-signal in single channels.
In order to get EMG-signals good enough for ergonomic evaluation the electrode position needs to be much more accurate, excluding the multi-channels approach to get redundant information. By means of extra padding over the electrode site both the position of the textile electrode can be better established and local perspiration stimulated which enhance the recording conditions.
RESULTS: We have made a prototype T-shirt with integrated textile electrodes enabling multi-channel recording of the ECG-signal. A signal processing technique based on adaptive filtering of the multi-channel signal was used to boost the R-wave of the ECG-signal. A simple level-detector can then identify the time instant of each R-wave and from that information the heart rate and heart rate variability follows. The technique can be applied in real-time and has proven to be quite robust towards missing channels or disturbances such as EMG from the trunk. Regarding the EMG signal, a padded structure above the trapezius muscle housing commercially available dry electrodes is the current intermediary solution.
CONCLUSIONS: Although further improvements are needed, our current experiences indicate that a smart textile T-shirt allowing long term recordings of heart and shoulder activity may be available to the research community in the near future. This would extend current possibilities in e.g. simultaneous long term monitoring of trapezius muscle activity and heart rate and heart rate variability, indicating psychological stress, which is of high interest in studies of musculoskeletal disorders of the neck and shoulder.

CONDUCTIVE ELASTOMER SENSORS IN NEUROLOGICAL REHABILITATION

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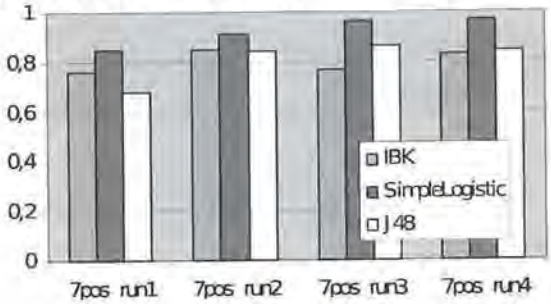
AIMS: Automatic recognition of posture of human body has important clinical applications. Functional recovery in patients affected by stroke and other neurological trauma can often benefit by early and continued rehabilitation; while initially the rehabilitation is followed inside specialized inpatient units, after discharge the continuity of care has a breach. One of the most promising applications is therefore the use of computerized telecommunication systems in order to detect and verify the execution of motor exercises prescribed to neurologically-ill patients.
METHODS: Recently, a novel type of sensor, based on conductive elastomers (CE) smeared on fabric, has been proposed for posture recognition. Sensors are deposited on a gar-ment as stripes. Advantages of CE sensors over solid-state and other types is their negligible weight and thickness, and the fact that any number of "measuring points" can be let on a garment in a single set-up. The impedance of each deposited segment varies as a function of the strain to which it is subject. Impedance is measured by a portable electronics front-end, and posture consequently recognized as a function of the sensor readings.
The task of posture recognition has been initially addressed in a supervised machine-learning framework. First, exercise protocol have been decided with discussion with physicians. Exercise paths (e.g. the adduction movement for upper limb) were divided in a series of intermediate steps. A subject was instructed to wear the sensorized gar-ment and to hold each of the chosen positions, while sensor readings were taken.
RESULTS: Several classification algorithms were tested. One model was built for each run, and evaluated against data acquired in the next run, used as an independent test set. Among the classifiers tested, those shown in figure yielded the best results. In order to implement a prototype for real-time classification, a single model was built with all of the runs available for a single subject merged together, in order to generalize as far as possible over all wearing conditions for a given person. For the runtime classification test, k=0.75 is obtained. This figure indicates a good agreement between model's response and real posture.



Postural recognition rate (K) for different algorithms

CONCLUSIONS: This paper described how the problem of posture recognition from multiple strain sensor readings has been tackled via supervised learning techniques. Approach provides a recognition rate high enough to suggest its use in a simplified posture rec-ognition task, which decomposes movements as a sequence of intermediate steps.

Research partially funded by IST project "MyHeart"

SENSORIZED FABRICS FOR HAND POSTURE AND GESTURE DETECTION

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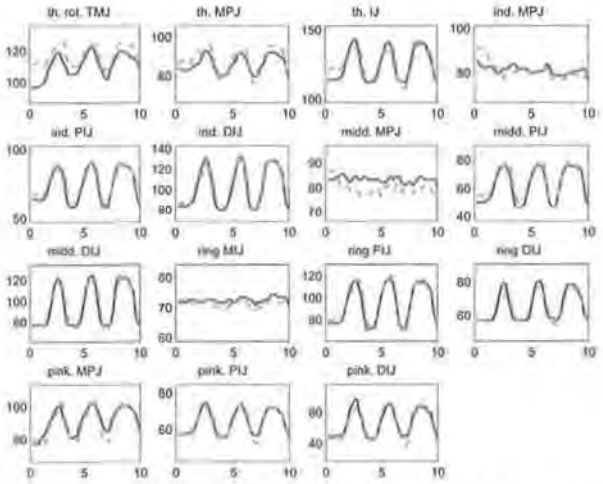
AIMS: Electrically Conductive Elastomer (CE) composites show piezoresistive properties when a deformation is applied. CE materials can be applied to fabric or to other flexible substrate and they can be employed as strain sensors. Our main aim in the present work was to realize a sensing glove able to detect hand posture and gesture and that can be worn for a long time with no discomfort. As a fundamental requirement to address the purpose we have estimated the employment of a material which does not substantially change the mechanical properties of the fabric and maintains the wearability of the garment. To obtain this result, we have integrated sensor networks made by CE into an elastic fabric used to manufacture the sensing glove.
METHODS: The sensing glove has been realized by directly smearing the CE (commercial product provided by Wacker LTD) on a Lycra/cotton fabric previously covered by an adhesive mask, according to the desired sensor topology. Piezoresistive CE sensors distributed over the glove can detect fabric local deformations produced by the user movement. Algorithms for mapping these raw sensor data into user kinematic configurations have been formulated in order to adopt the presented sensing system in biomechanical reconstruction. In particular, to validate our sensing glove as a posture detection system we have used a commercial device used for hand movement analysis: the Cyberglove® produced by Immersion corporation. During the calibration phase, the CE glove was worn by a subject together with the Cyberglove®. The subject was asked to perform natural hand movements for about three minutes. Data from the CE glove and from the Cyberglove® were simultaneously acquired. In this way it has been possible to construct a map F that relates CE glove signals to hand movements.



Acquisition of joint angle values for 15 hand degrees of freedom. dashed lines are the CE sensing glove outputs while continuous lines are Cyberglove® outputs

RESULTS: In the test phase, the CE glove and the Cyberglove® were worn by the same subject during natural hand movements. Data from the CE glove were processed by the map *F* and outputs were compared with the ones produced by the Cyberglove®. Results are encouraging. A test trial is reported, as an example, in Figure.
CONCLUSIONS: The realized sensing glove has shown very promising performances in terms of reconstruction of hand segment position.

EXPERIMENTS IN THE DETECTION OF UPPER LIMB POSTURE THROUGH KINESTETIC STRAIN SENSORS

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AIMS: Conductive elastomers (CE) are a novel strain-sensing technology which can be embedded unobtrusively into an elastic garment's fabric. Elasticity of the garment lead to strong cross talk phenomena between sensors. In order to address this problem, in this paper an analysis of the attributes (attribute selection), by computing the *information gain* (IG) is performed. A prototype was realized to simultaneously measure the strains at multiple points of a shirt covering the thorax and upper limb. This work describes preliminary experiments with machine learning techniques, employed to analyze the strain measures in order to reliably reconstruct upper-limb posture. The aim of the application is to detect execution, correctness and progress of physical exercises performed as part of neurological rehabilitation therapy.
METHODS: When CE sensors are deposited on a garment as stripes, the impedance of each deposited segment varies as a function of the strain to which it is subject. Advantages of CE sensors over solid-state and other types is their negligible weight and thickness, and the fact that any number of "measuring points" can be let on a garment in a single setup. The garment is able to detect body postures taken by patients while performing prescribed exercises for physical rehabilitation after discharge by the rehab clinic. After the garment is worn a subject is asked to perform one of several rehabilitation exercises foreseen in the rehabilitation protocol. This is done in order to "snapshot" the current sensor readings. The values are stored and later used as the training set to build a posture-recognition model. The aim of the final system is to discriminate not only the progress along the correct execution, but also warn in case one of the improper positions is attained. In this simplified setup, therefore, we are dealing a supervised classification task, with 19 numeric attributes (sensors). Class labels, or target postures, will be assigned among a set which includes n intermediate steps taken in the "correct" exercise execution path, and m "incorrect" positions. For tests to be described in the following we have preliminarily fixed n=4 and m=3.
RESULTS: Before testing actual classification schemes, a preliminary exploration on attributes (attribute selection), by computing the *information gain* (IG) of each single attribute, has been performed. Figure shows the IG values, in bits, of the 19 sensors as measured in upper limb adduction, sorted in descending order. Values obtained confirm the dependence between sensor location and joints. Data are currently under treatment to joint movement model by using k-statistic methods.

Information gain for each sensor

T15.P01
LIDWINE - A EUROPEAN PROJECT ON PREVENTION AND TREATMENT OF BEDSORES

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AIMS: This project aims at developing technologies and materials for prevention and treatment of bedsores. The aim is to achieve a proof of concept. The research includes massage, electrostimulation, reduction of friction, moisture management and antimicrobial textiles. These technologies and materials should be integrated or transformed intot extiles. Apart from technological research, the project also includes training and education and a close dialog with medical people. The paper aims at informing the audience on the project in order to get feedback on the different uses of electrostimulation.
METHODS: Electrostimulation will be used to prevent bedsores by reinforcing the skin and underlying tissue and to stimulate the healing process. Textile electrodes will be developed to this end. The research will focus on current density inside the textile electrodes in order to prevent burning injuries at the electrode edges. Electrodes with self controlling conductivity will be designed.
RESULTS: The project will start only in spring 2006, so no results are available yet.
CONCLUSIONS: Bedsores are an increasing problem. They require long and expensive treatments, reduce quality of life and often lead to death. The textile materials to be developed supported by the appropriate training and dissemination methods will reduce the incidence and healing time.

T15.P02
A WIRELESS INTELLIGENT SENSOR FOR REAL TIME ADL MONITORING

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AIMS: The interest of Activities of Daily Living (ADL) monitoring is bound to the possibility to observe patient activity in the home environment with a minimally invasive system. The recent availability of high performance microcontrollers and wireless connectivity at low cost has made the design of new applications in this field possible. Recent encouraging works (Mathie et al. 2004, Bussmann et al. 2001) demonstrated that it is possible to infer significant data by using only a limited number of sensors. The aim of this work is to design a new-concept real-time classification tool for a predetermined set of motor activities. Unlike other wireless systems this tool elaborates data on board minimizing the amount of data to be transmitted to the gateway or making possible a long term monitoring as data logger.
METHODS: The classification is obtained comparing analog accelerometer signals (Analog Devices® ADXL203 for biaxial measures and Freescale® MMA7260Q for triaxial measures) with a set of signal templates. Each template corresponds to a different motor activity (i.e: walking, descending stairs etc.) and can be previously extracted in laboratory with a gait analysis system. The comparison is made with a cross-correlation algorithm. Previous works (Veltink et al. 1996 and Caselli et al. 2005) demonstrated that it is possible to reach recognition rates over 90% using cross-correlation algorithms. In order to reduce algorithm complexity a knowledge base was introduced to determine which signal has to be compared with which template and which threshold on cross-correlation should be used.
A 32-bit and floating-point cross-correlation algorithm was implemented (in basic language) on a Microchip microcontroller dsPIC30F3013. Signals were low-pass filtered at 20 Hz and sampled at a frequency of 100 Hz with a 12 bit resolution. Memory space on such microcontrollers is enough to store a 16-bit 100-Hz set of templates. For wireless transmission a PAN1560 Bluetooth module was used at 9600 baud/s. The system can be switched via remote control to transmit mode and can be used as a wireless accelerometer sensor.
RESULTS: Results obtained with dsPIC microcontroller at 120MHz clock frequency show that it is possible to execute the cross-correlation algorithm in less than 5 ms during simulation. This performance, considering the time needed for sampling and for buffer shift, permits the elaboration of one cross-correlation algorithm at every sampling time period. The time needed for overall classification is thus dependant on the number of considered activities and on the rules determined by the knowledge base.
CONCLUSIONS: The performance of dsPIC microcontrollers proved to be adequate for the computational load required. The tool has a cost for building a single prototype unit of less than 100 USD. The single unit has limited dimension (21x49x10 mm plus battery). Further developments will include similar tools for posture classification by filtering low frequency data of accelerometer signal. As a final step the whole data can be elaborated in order to obtain the desired time resolution: from the single execution of one step to the construction of daily, weekly or monthly reports regarding motor activity.

T15.P03
TRIGGERLESS DETERMINATION OF BALLISTOCARDIOGRAPHIC WAVEFORMS

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AIMS: The force generated by the cardiac activity can be measured while standing on a force plate [1]. From the resulting ballistocardiographic (BCG) waveforms, it is hypothesized that a curve-fitting model could eventually provide a non-invasive estimation of the stroke volume. Until now, the recognition of the BCG waveforms required the use of an electrocardiographic (ECG) signal, using the R-wave as a trigger. In this work, we propose a pattern recognition method that determines the BCG waveforms and locates each heart beat occurrence using exclusively the force signal.
METHODS: Data were acquired from 10 male subjects (age 23-33, weight 66-85 kg, height 170-190 cm) who were asked to remain still for a period of 90 s on a force plate. For each subject, six trials were carried out (3 seated, 3 standing), for a total of 60 force signals, along with 60 ECG signals acquired for validation of the algorithm. The BCG waveforms were determined after a series of analyses of the signal. Initially, the signal was broken down into segments showing significant activity. These segments were then aligned and averaged to create a temporary template. In the subsequent passes, the template was cross-correlated with the force signal. Time lags with a high correlation index helped create new sets of segments that were once again aligned and averaged. This procedure was carried out until no significant difference was noticeable on the templates from one iteration to the next.
RESULTS: The determination of the BCG waveforms was fully automatic, i.e. no operator intervention was required for any of the 60 signals analyzed. The detection accuracy for the trials carried out in a seated position (93,0%±10,0%) was similar to the one in the upright position (91,9%±11,4%). False negatives outnumbered false positives by a 2 to 1 ratio. Waveforms obtained while seated had different features than those obtained when standing up. The latter had a larger peak-to-peak amplitude giving a greater rectified area and more oscillations were present. In each task, intra-subject variability was not noticeable. As for the inter-subject variability, it was quite significant: the BCG waveforms did not show any predictable behaviour that could be characterized with standard parameters such as height or weight.
CONCLUSION: With the proposed algorithm, it is possible with only a force plate signal to determine the BCG waveforms and reliably locate most heart beat occurrences from force signals generated by subjects in a seated or in the upright position.

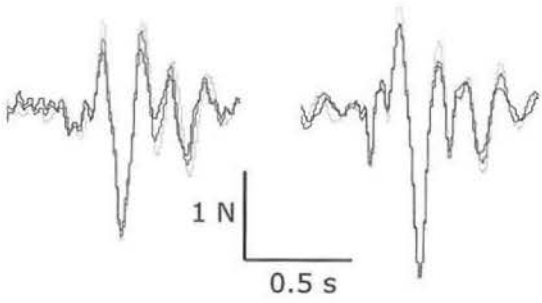

Figure 1. Typical BCG waveforms obtained in a seated (left) and in an upright position (right).

1) S. Conforto, M. Schmid, V. Camomilla, T. D'Alessio, A. Cappozzo, "Hemodynamics as a Possible Internal Mechanical Disturbance to Balance," Gait and Posture, vol. 14, pp. 28-35, 2001.

T15.P04
ACTIVITY CLASSIFICATION USING TIME-DEPENDENT NEURAL NETWORKS

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AIMS: The goal of this work is to determine if there are any advantages to deploying time-dependent as opposed to equivalent static neural networks for the task of activity classification when a subject wearing surface electromyographic (sEMG) and accelerometer (ACC) sensors is asked to perform a scripted time-series protocol of activities. The use of time-dependent neural networks is based on the need of improving classification performance for some activity categories that have a significant non-stationary temporal dimension to their defining characteristics.
METHODS: Four healthy subjects (21-25 years old; 2 females, 2 males) were asked to follow a series of scripted tasks sequentially and complete the required duration or repetitions for each task. The scripted time-series protocol consisted of 11 functional tasks that we wanted to identify ("ID tasks", e.g. feeding, walking, supine-to-sit, etc.) as well as 4 other similar tasks that were included to test the ability of neural networks to differentiate them from the ID tasks ("non-ID tasks", e.g. sitting, standing). Each subject was asked to perform the scripted time-series protocol twice while being videotaped to provide a benchmark for assessing the performance of the neural networks on the sEMG and ACC data.
A time-dependent neural network was designed to process the data acquired from each subject using 8 pairs of sEMG and ACC sensors. The inputs to the time-dependent neural network were features extracted from 4-sec intervals with 50% overlap. Furthermore, a static neural network was designed as the asymptotic equivalent of the time-dependent neural network in order to compare the performance of these two types of neural networks in terms of their classification accuracy as well as training time.
The time-dependent neural network and its static equivalent were initially trained on half of the data from each subject while the other half was used for testing the classification accuracy.
A task was considered "correctly identified" by a given neural network if at least 50% of the 4-sec intervals that included the task were identified as such by the neural network.
RESULTS: As exemplified in Table 1, it was found that time-dependent neural networks outperformed the equivalent static neural networks in classifying transitional activities such as "supine-to-sit" that were carried out in a dynamic time-series context. This is due to the fact that time-dependent neural networks require fewer parameters to be trained than the static neural networks and therefore can be efficiently generalized during the training process.
CONCLUSIONS: Our experimental results indicate that time-dependent neural networks are preferable to static neural networks for the purpose of classifying functional activities that take place in a dynamic time-series context.

Task	Correct Identification	
	TDNN	Static NN
Walking	Yes	Yes
Sitting	Yes	Yes
Supine-to-sit	Yes	No

Examples of classification results.

This project was funded by NIDRR Field-Initiated Project Award # 133G020108.

T15.P05
ADJUSTING DBS SETTINGS TO OPTIMIZE PARKINSON'S CONTROL THERAPY

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AIMS: Parkinson's Control Therapy by Deep Brain Stimulation (DBS) is used to reduce Parkinsonian symptoms in late stage Parkinson's Disease. Clinicians adjust pulse amplitude, pulse width, frequency, and electrode selection to maximize symptom suppression while minimizing side effects. There is a need for a quantitative method to perform these adjustments. The aim of this study was to characterize the effects of on-off DBS parameter adjustments with data from wearable sensors.
METHODS: Five subjects with implanted DBS for Parkinson's Control Therapy were recruited in the study. Single-axis accelerometers were placed on the lateral aspect of the upper and lower arms, thighs, and shins and were oriented in the anteroposterior direction. EMG electrodes were attached to the biceps, triceps, finger flexor, and finger extensor muscles on the more affected side and to the tibialis anterior and the gastrocnemius medialis muscles on both legs. Subjects performed selected tasks from the United Parkinson's Disease Rating Scale for 30 s including finger tapping, finger to nose, heel tapping, and walking. Tests were performed 5-6 times: with the DBS on, immediately after turning the DBS off and every 30 min afterward, and finally after the DBS was turned on again. Five-second windows were selected to extract features including the RMS value, the dominant frequency, an index of periodicity, the range of the autocovariance function, the approximate entropy, and cross-correlation coefficients for pairs of sensors. Data visualization was obtained using Principal Components Analysis combined with Sammon's Mapping to identify trends in the severity of symptoms.
RESULTS: Large changes in tremor, bradykinesia, dyskinesia, and gait patterns were seen between tests with the DBS turned on and off. Smaller differences in the severity of symptoms were detected between test sessions when the DBS remained off.

Figure 1 shows the difference in tremor between the on and off states for one subject. Tremor can be seen in the accelerometer and EMG signals when the DBS was off, but no tremor is apparent during the on state. These changes were captured by the dominant frequency, index of periodicity, and RMS values. Visualizations of these features showed that the severity of tremor changed across time as the DBS remained off.

CONCLUSIONS: This work shows the ability of a sensor system to detect changes in Parkinsonian symptoms caused by turning the DBS on and off. The system was able to detect small changes in symptoms while the DBS remained off. This observation suggests that a sensor system may be able to detect changes in the severity of symptoms during clinical DBS parameter adjustments.

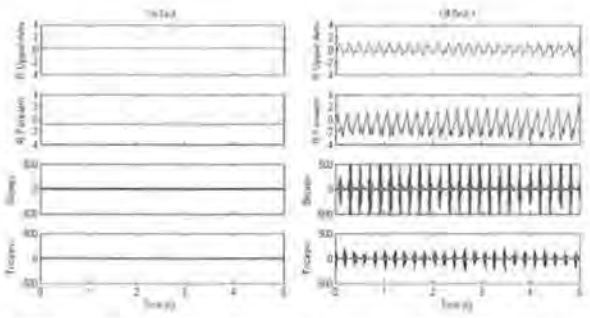

Figure 1. Patterns associated with tremor with the stimulator on (left panel) and the stimulator off (right panel).

T15.P06
MOTION MONITORING WITH WEARABLE SENSORS

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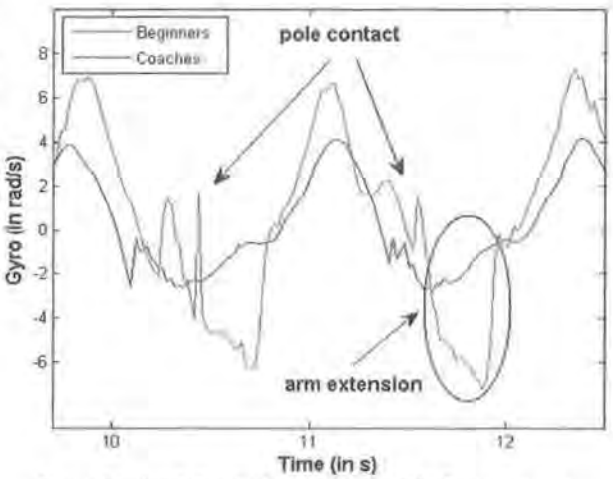
AIMS: The most successful motion analyses approaches use markers and complex video equipment and are thus bound to more or less stationary laboratory conditions. To get out of the constrained laboratory setting a number of groups has recently started to investigate the use of wearable inertial sensors. This work focuses on using such sensors to analyse motion patterns during outdoor physical activities, such as Nordic Walking and cross-country skiing.

METHODS: To detect motion patterns of lower und upper extremities, we used six 3D Motion Tracker sensors (MT9, XSens) consisting of accelerometers and gyroscopes. The sensors were attached with elastic bands to shanks, thighs and forearms and located at bony areas in order to minimize sensor displacements due to muscle belly vibrations. Five Nordic Walking coaches and five beginners were asked to perform Nordic Walking (i.e., walking using hiking poles) on a 40-m uphill walkway (21%) at a self-selected speed. The movement patterns of the coaches were used as a gold standard for comparisons. The signals were sampled with 100 Hz and transmitted via Bluetooth to a wearable computer which analyzed the data.

RESULTS: Coaches showed higher angular velocity (sagittal plane) compared to beginners in terms of arm extension and toe-off phase (figure below). These differences in signals provided a relevant feature subset for a simple classifier algorithm. The algorithm classifies relevant techniques (inappropriate movements) and level of performances (normal, medium and progressive Nordic Walking).

CONCLUSIONS: Overall, the wearable motion system provides real-time feedback to the individual motion patterns. Thus, beginners will be able immediately to adhere to correct techniques and to optimize their walking style. The system might be adapted for other sports activities (hiking, cross-country skiing) and be applied to medical rehabilitation (e.g., Neurology and Orthopaedics).



Gyroscope signals (sagittal plane) of the right forearm sensor.

T15.P07
WEARABLE FORCE SENSORS FOR DETECTING MUSCLE ACTIVITY AND MUSCLE FATIGUE

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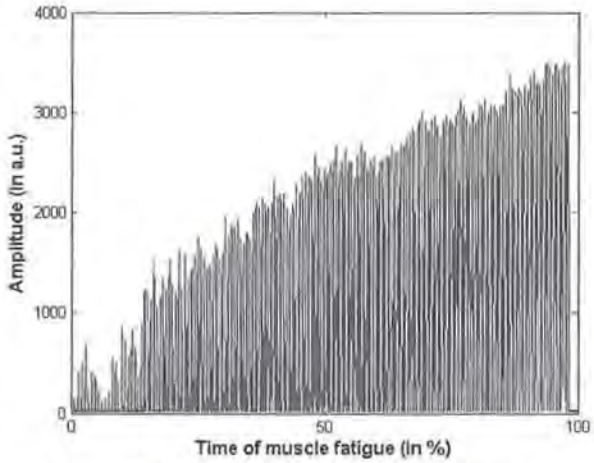
AIMS: Muscle fatigue is associated with noticeable changes of muscle volume ('inflation') resulting in an increased blood circulation within the muscle. By using practical force-sensitive resistor sensors placed on the front leg muscle surface, we propose to detect muscle activity and muscle fatigue through variation on mechanical pressure that the muscle surface exerts on the sensor.

METHODS: We have used force-sensitive resistor (FSR-153NS) sensor. The signals were sampled with 100Hz and 12 bit resolution. To adjust the sensor to right m. vastus lateralis, placed according to international standards for EMG, a commercial elastic band was tightened in increments of two centimetres until reaching between 15% and 20% of the maximum signal (as given by sensor range) during 90° knee flexion squats. Subsequently, ten healthy male subjects performed dynamic squats (1 Hz) to individual maximal leg muscle exhaustion. Paired t-test and Pearson's correlation were calculated. Values below were given as mean±SD.



Example for FSR sensor signals during fatiguing squats.

RESULTS: The time of maximal muscle fatigue ranged from 104 to 403 s among the subjects. An increase of 358 (±203) % in signal amplitude was registered in 'totally exhausted' leg muscle condition compared to 'fresh' (1050±445 vs. 3267±824 a.u.; $P<0.001$). During strenuous squats, no correlation between time of total muscle fatigue and percentage changes in signal amplitude were shown ($P=0.49$; $P>0.05$).

CONCLUSIONS: We have demonstrated that the amount of muscle inflation detected by FSR sensors can be seen as an objective muscle fatigue indicator. Compared to EMG, these sensors are low priced and more suitable (i.e., attachment and signal processing) for wearable applications. We envision the sensors to be integrated in practical elastic bands or pants for assessing muscle activity, muscle fatigue or body motion that might be of interest to medical, nursing and sports applications.

Spasticity

SPASTICITY ASSESSMENT:THE NEED FOR STANDARDIZATION

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AIMS: As spasticity is known to be dependent on muscle length, the positioning of subjects during testing is likely to influence the results of such measurement. In the literature, studies of stretch reflex activity related to muscle length are contradicting, especially concerning the quadriceps muscle (Burke et al, J Neurol Neurosurg Psychiatry. 1970; He, IEEE Trans Rehabil Eng. 1998; Kakebeeke et al, Spinal Cord. 2002;Vodovnik et al, Med Biol Eng Comput. 1984).
Objective of this study is to investigate the influence of two positions, sitting and supine lying, on stretch reflex activity, measured by surface electromyography (sEMG), of the rectus femoris (RF), vastus lateralis (VL) and semitendinosus (ST) muscle, and its' reflection on the Ashworth scale.
METHODS: 19 patients (≥6 months post-stroke) were recruited from an out-patient department of a Rehabilitation Centre. All patients were able to understand simple commands and had adequate hip and knee mobility without other (joint) complaints. In this crossover trial the study population was randomized, with one group starting in sitting and the other in supine position. Block randomization of the order of positioning was performed mainly because of the occurrence of fatigue in repeated stretching of a spastic muscle.
Resistance to passive movement was assessed with the Ashworth scale by a (blinded) physiotherapist. Surface EMG and synchronized knee angle were measured during the pendulum test and the passive movement test. The whole procedure was then repeated in the other position. Data were compared by using the paired t-test for continuous variables and the Wilcoxon signed-ranks test for ordinal values.
RESULTS: PENDULUM TEST: Duration of the first knee flexion and extension were lower in supine position (mean difference 125.6 msec; P<0.001 for flexion and 65.7 msec; P=0.004 for extension). The amplitude of both halves of the cycle decreased as well (12.1°; P<0.001 and 7.1°; P=0.026). The Relaxation Index was also lower in supine position (P=0.001). The RMS-values of the first burst in RF and VL were both significantly higher in supine position (RF P= 0.006; VL P=0.049).
PASSIVE MOVEMENT TEST: RF burst activity was significantly higher in supine position (mean difference RMS -4.0 μV; P=0.007). The RMS of ST during extension was higher in sitting position (mean difference 6.6 μV; P=0.017).
ASHWORTH SCALE: In supine position significantly higher Ashworth scores for the knee extensors (Wilcoxon signed ranks test; P=0.001) and lower scores for the knee flexors (P=0.002) were found.
CONCLUSIONS: Clinical and neurophysiological assessment of spasticity is influenced considerably by change in posture and muscle length. For comparable assessment of spasticity exact documentation of the patients' position is essential. We strongly support earlier recommendations to standardize testing protocols for both clinical and neurophysiological measurements.

A COMBINED METHOD FOR THE CLINICAL ASSESSMENT OF SPASTICITY

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AIMS: Spasticity is a complex phenomenon, associated with an upper motor neuron lesion (UMN) and is defined as disordered sensorimotor control presenting as intermittent or continuous involuntary activation of muscles [1]. Currently available clinical assessment methods are subjective, characterized by low test-retest and inter-rater reliability, and do not provide good correlations with other spasticity measures [2]. A combination of methods comprising biomechanical and neurophysiological methods, applicable to a clinical setting, is recommended [3, 4]. Therefore, the Spasticity Measurement Tool (SMT) has been developed, integrating hand-held dynamometry, goniometry, and sEMG, to assess spasticity in the wrist flexor muscles. It consists of a trough for the forearm and hand with a hinge mechanism at the wrist. The sEMG signals of the wrist flexor and extensor muscles, wrist angle, and exerted external force are synchronised and recorded using a blue-tooth ambulant measurement device. Aim of this study was to investigate the clinometric properties of this SMT to assess spasticity.
METHODS: Eleven healthy subjects and 12 age- and sex-matched patients with chronic post-stroke spasticity participated in the study. Subjects were positioned in a stable chair next to a table with the dominant (in controls) or affected (in patients) forearm in a trough such that the elbow was flexed 90° with minimal shoulder abduction and the arm in the same plane as the body. Surface electrodes (ARBO H93, solid gel, 24 mm interelectrode distance) were placed at the flexor carpi radialis and the extensor carpi radialis muscles. Sample frequency was 512 Hz and data were filtered 15-250 Hz. Measurements consisted of passive Range of Motion (pROM) and passive wrist extensions at different velocities timed to a metronome (PM1, PM2, PM3). Outcome measures were pROM (in deg), muscle response to passive movement (RMS) and resistance to passive movement (N/deg). Prior to the measurements the Ashworth score was assessed as a clinical measure of resistance to passive movement. Subjects were measured twice on two consecutive days to study test-retest reliability, and a sample of the subjects was also measured by different examiners to study inter-rater reliability. Restricted Maximum Likelihood Estimation was used to calculate reliability coefficients, and Spearmans' rho was used to explore the association between SMT outcome and Ashworth scale (AS).

RESULTS and CONCLUSIONS: Preliminary results show moderate to high test-retest reliability (coefficients 0.65-0.97) and inter-rater reliability (0.65-0.99), except for the inter-rater reliability coefficients for RMS of the wrist flexor during PM2 and PM3 (.55 and .29 respectively). This is likely to be related to stretch reflex adaptation caused by repetitive movement (e.g. [5]). AS was significantly associated with resistance to passive movement (rho = .73, p = .03) and RMS of the flexors (rho=.64, p=.05) both during PM1.
Results indicate that the SMT may attribute to improve management of spasticity by providing clinicians with an objective spasticity measurement tool.

[1] Pandyan et al., Disabil rehabil, 2005
[2] Platz et al., Disabil rehabil, 2005
[3] Voerman et al., Disabil rehabil, 2005
[4] Wood et al., Disabil rehabil, 2005
[5] Schmit et al., Arch Phyc Med Rehabil, 2005

PATHOLOGICAL CLONUS: A CENTRAL OR A PERIPHERAL DISORDER?

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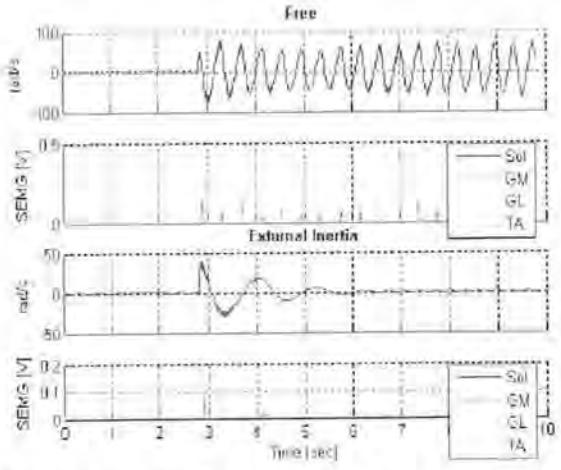
AIMS: Pathological clonus is common to central lesions of the CNS like e.g. in SCI and stroke. Research to the origin of clonus is still contradictory, in favour to either a central oscillatory mechanism or a peripheral feedback path. This study aims to reveal the origin of pathological clonus from experimental measurements and model simulations.
METHODS: Clonus data from 10 stroke patients have been collected from recordings made on an ankle manipulator. Recordings were made from the ankle angle, torque and surface electromygrams (SEMG) of eight leg muscles, of which the ankle plantar flexor muscles (SOL, GM, GL) and the dorsiflexor muscle (TA) were most relevant. Clonus was induced in all patients by brief force pulses that dorsiflexed the foot and often sustained for tenths of seconds. We presumed clonus to be of peripheral nature when found positive to the following tests: i) clonus frequency increases with additional stiffness, ii) - decreases with additional inertia and iii) clonus is uniquely predicted when increasing the sensory-motor gain involved in the reflex path. Failing of all tests would indicate a central origin. For clonus prediction, a model was used including muscle contraction dynamics (linear visco-elasticity), muscle activation dynamics representing Ca^{2+} in- and outflow, foot inertia, neural feedback (unidirectional feedback of stretch and stretch rate from the muscle spindles), feedback gains and neural delay.
RESULTS: Figure shows an induced clonus for a typical patient (upper traces). Clonus decayed in most cases when inertia was added to the foot (lower traces) and clonus frequency increased with added stiffness. The model predicted the clonus when the velocity feedback gain was increased (not shown for concision).
CONCLUSIONS: The results in this study strongly suggest that pathological clonus is of peripheral nature and is likely the result of an elevated gain in the sensory motor feedback path. These findings correspond to hyper reflexes as frequently found in central lesions. From the brief and large responses in the SEMG it appears that oscillatory movement sustains from periodic emergence of reflexive force. The current model needs to be extended in order to simulate the SEMG for validation and for inclusion of more detail.



Clonus records during free movement (upper two traces), with external inertia (lower two traces)

MOTOR UNIT DECOMPOSITION OF LAYRNGEAL MUSCLES IN SPASTIC DYSPHONIA

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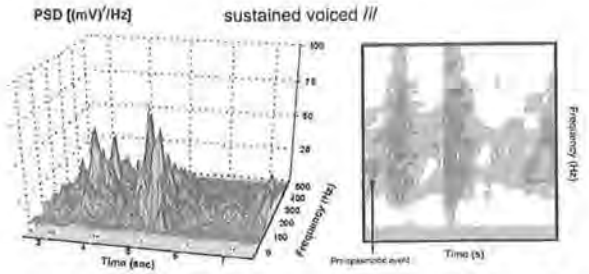
AIMS: Spasmodic dysphonia (SD) is a neurogenic voice disorder caused by involuntary movement of one or more muscles of the larynx, resulting in strain-strangled voice quality that ranges from moderate to severe. SD affects a significant population, impacting both quality of life and professional duties. The cause of SD is unknown and little is understood about its underlying neurophysiological mechanisms. Improved diagnostic, prognostic, and treatment methods are being sought by many investigative teams.
METHODS: We acquired electromyographic (EMG) signals from intralaryngeal muscles (thyroarytenoid and cricothyroid) of a clinical population of SD patients using quadrifilar needle electrodes while subjects performed a variety of vegetative and phonatory tasks. We applied time-frequency transforms to composite EMG signals to explore 'frequency and power content' over the time-course of muscle activation (e.g., during pre-phonatory organization and phonatory segments). Precision Decomposition II was applied to array-EMG signals to obtain mean firing rate and recruitment (bar) plots of simultaneously-active motor units and their constituent motor unit action potential trains. Three-dimensional measures of correlation across motor unit pairs were obtained over the time course (surface CC plots). Results were compared to a corpus of normal subjects.
RESULTS: Spasmodic dysphonia patients exhibit abnormal EMG interference patterns from a time-frequency perspective, whereby pre-spasmodic 'disorganization' events are often identified prior to spasm. Three-dimensional CC plots suggest that MU 'common drive' is decreased during incidences of spasm compared to episodes of non-spasm within patients, and when compared to normals.
CONCLUSIONS: MU decomposiion is providing a useful tool to explore this spastic disease at the level of the lower motoneurons. SD patients exhibit varying levels of MU organization and control over the course of laryngeal motor function.



Time-Frequency power of laryngeal EMG signals of patients with spastic dysphonia. A pre-spasmodic power-frequency 'event' is noted before the first spasm

Sports, Elderly and Space Medicine and Human Performance

EMG-ANGLE RELATIONSHIPS OF THE KNEE EXTENSORS IN FEMALE ADOLESCENT ATHLETES

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AIMS: The EMG-angle relationships fail to be described by a consistent relationship (Lunnen, et al., 1981; Pinniger et al., 2000; Eloranta & Komi, 1981; Mohamed et al., 2002). Since sport background has been found to alter the torque-angle relationship of the knee extensors (Herzog et al. 1991) as well as their coordination during jumping (Eloranta, 2003) the aim of the study was to examine whether sport background possibly determines the EMG-angle relationships of the knee extensors.
METHODS: Twenty young female track & field jumpers (J) and 21 volleyball players (V), (13-19 years), participated in the study. The activity of rectus femoris (RF), vastus medialis (VM) and vastus lateralis (VL) was recorded during isometric knee extension at nine joint angles (every 10 deg at 10-90 deg range of motion, with 0 deg defined as full knee extension) and the EMG integral at maximum isometric torque value was calculated. Curve fitting (SPSS 10.0) was applied, separately for each one of the participants and each muscle, to identify the function that best described the EMG-angle relationships.
RESULTS: A variety of functions described the EMG-angle curves (Table), with the quadratic function that describes the increase of EMG activity when the knee angle increases to knee flexion, being the predominant one. No systematic pattern of differences was observed between track and field jumpers and volleyball players or among muscles.
CONCLUSIONS: Sport background does not appear to affect the EMG-angle relationships of the knee extensors. The representative EMG-angle curve for the female adolescent J and V is the one that describes an increase of EMG activity when the knee joint angle changes from an extended position to a flexed position.

EMG-angle curve 10⇒90deg	RF			VM			VL		
	J	V	*Sum*	J	V	*Sum*	J	V	*Sum*
	5	6	***11***	4	4	***8***	4	4	***8***
	5	5	***10***	8	4	***12***	10	7	***17***
	5	3	***8***	2	3	***5***	2	1	***3***
	1	5	***6***	4	3	***7***	2	5	***7***
	2	1	***3***	1	3	***4***	1	2	***3***
	0	0	***0***	0	1	***1***	0	0	***0***
	1	0	***1***	0	2	***2***	0	1	***1***
	1	1	***2***	1	1	***2***	1	1	***2***

Frequency EMG emg-angle curves of rectus femoris (RF), vastus medialis (VM) and vastus lateralis (VL) for the track and field jumpers (J) and the volleyball players (V)

Eloranta and Komi (1981). Electromyogr Clin Neurophysiol, 21, 419-431.
Eloranta (2003). Electromyogr Clin Neurophysiol, 43, 141-56.
Herzog et al. (1991). Med Sci Sports Exerc, 23 1289-1296.
Lunne et al. (1981). Phys Ther 61, 190-195.
Mohaned, et al. (2002). Clin Biomech, 17, 569-579
Pinniger et al. (2000). Eur J Appl Physiol 81, 375-383.

RELIABILITY OF ELECTROMYOGRAPHY IN SQUAT JUMPING

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AIMS: The fundamental basis of all electrophisiological analisys is without a shadow of a doubt the analisys of excitable cells and their corresponding action potentials. In this way the inherent reliability of the data obtained struggles to achieve it's main goal of maximally removing assessment error. Hence mandatory reliability validation is required to ensure data comparison liability. The main purpose of our study was to assess the intraclass reliability of selected EMG variables in squat jumping (SJ). In this way we aimed to verify the reliability of surface electromyography in high speed body-segment movements, without electrode removal after one hour rest, as well as with electrode removal after a one week resting period.
METHODS: In order to achieve this purpose we assessed a group of 8 subjects (4 male and 4 female). We focussed on the analysis of the average EMG full wave rectified signal, it's iEMG and the corresponding root mean square. This analisys was performed using surface electrodes (BlueSensor, Medicotest) and concerned the lower limb's vastus lateralis, vastus medialis, internal gastrocnemius, external gastrocnemius and biceps femoris muscles. Thus in order to evaluate SJ reliability subjects performed two SJ one hour apart from each other without electrode removal and two SJ one week apart with electrode removal. For statistical validation we used the Intraclass Correlation Coefficient in all variables.
RESULTS AND CONCLUSIONS: Our results demonstrated that all selected EMG variables revealed high reliability both with (ICC values between 0.72 and 0.96) and without electrode removal (ICC values between 0.89 and 0.99), allthough the values obtained with electrode removal were slightly lower but still strongly reliable. Flight time values were also highly reliable contributing for the validation of jump comparison between different assessments. Hence our results apparently demonstrated that SJ EMG analisys is liable as well as highly reliable with and without electrode removal.

Squat Jumping		Without Electrode removal					With electrode removal				
		Before		After			Before		After		
		Mean	SD	Mean	SD	ICC	Mean	SD	Mean	SD	ICC
Avg	VL	0,481	0,245	0,493	0,202	**0,98**	0,484	0,209	0,578	0,162	**0,90**
	VM	0,442	0,125	0,440	0,125	**0,95**	0,433	0,107	0,431	0,079	**0,89**
	GI	0,237	0,096	0,245	0,092	**0,98**	0,239	0,094	0,275	0,095	**0,96**
	GE	0,225	0,058	0,215	0,079	**0,84**	0,213	0,062	0,261	0,101	**0,72**
	BF	0,106	0,041	0,113	0,058	**0,91**	0,108	0,050	0,138	0,044	**0,84**
iEMG	VL	0,246	0,118	0,221	0,096	**0,96**	0,241	0,100	0,294	0,101	**0,83**
	VM	0,225	0,061	0,224	0,064	**0,98**	0,225	0,063	0,243	0,077	**0,72**
	GI	0,128	0,063	0,124	0,053	**0,99**	0,128	0,062	0,158	0,048	**0,94**
	GE	0,116	0,039	0,109	0,048	**0,98**	0,110	0,041	0,149	0,071	**0,83**
	BF	0,054	0,021	0,058	0,021	**0,95**	0,055	0,023	0,061	0,029	**0,85**
RMS	VL	0,668	0,281	0,643	0,242	**0,98**	0,678	0,246	0,773	0,269	**0,82**
	VM	0,608	0,155	0,606	0,141	**0,93**	0,614	0,140	0,743	0,245	**0,80**
	GI	0,368	0,144	0,368	0,153	**0,97**	0,375	0,156	0,474	0,124	**0,87**
	GE	0,345	0,122	0,328	0,139	**0,99**	0,325	0,130	0,388	0,152	**0,82**
	BF	0,178	0,107	0,155	0,070	**0,79**	0,175	0,113	0,171	0,077	**0,55**
Avg/t	VL	0,964	0,535	0,898	0,456	**0,98**	0,943	0,466	0,958	0,389	**0,87**
	VM	0,981	0,294	0,886	0,304	**0,90**	0,850	0,230	0,825	0,266	**0,75**
	GI	0,461	0,159	0,488	0,178	**0,94**	0,463	0,158	0,518	0,133	**0,87**
	GE	0,447	0,111	0,430	0,158	**0,89**	0,416	0,122	0,476	0,155	**0,43**
	BF	0,214	0,092	0,231	0,149	**0,89**	0,218	0,122	0,213	0,109	**0,84**
iEMG/t	VL	0,484	0,240	0,444	0,206	**0,98**	0,474	0,207	0,631	0,246	**0,82**
	VM	0,441	0,129	0,445	0,124	**0,95**	0,435	0,109	0,441	0,141	**0,78**
	GI	0,244	0,093	0,243	0,096	**0,99**	0,243	0,093	0,279	0,100	**0,96**
	GE	0,210	0,069	0,216	0,081	**0,96**	0,214	0,067	0,266	0,099	**0,75**
	BF	0,106	0,045	0,119	0,054	**0,84**	0,111	0,053	0,114	0,042	**0,81**
TV		0,471	0,043	0,478	0,046	**0,97**	0,480	0,043	0,603	0,049	**0,90**
DF		0,512	0,073	0,505	0,066	**0,87**	0,515	0,077	0,551	0,071	**0,49**

Mean, Standard Deviation (SD) and ICC of Flight time (FT), phase duration (DF) as well as EMG variables recorded in SJ from VL,VM,GI,GE and BF muscles, with and without electrode removal

CORRELATIONS BETWEEN FLIGHT TIME AND SURFACE EMG RESPONSES TO CONTINUOUS JUMPING TEST

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AIMS: 1) To assess the feasibility of recording surface electromyographic (sEMG) signals during continuous jumping test, adopting linear electrode arrays; and 2) To correlate mechanical performances and the sEMG variable estimates thus obtained.
METHODS: Thirteen athletes (9M, 4F, 23.9±3.3 years) performed a test of 60 s continuous jumping during which the flight time and the sEMG signals were recorded. sEMG signals were recorded using adhesive linear electrode array (eight channels, 10 mm apart) placed on the vastus lateralis muscle of the dominant leg. Special care was taken in electrode placement to avoid the effect of the innervation zone shift due to the muscle shortening and lengthening. An electrogoniometer was placed on the controlateral joint to record the time course of the knee angle.
sEMG variables were estimated during the concentric phase (CP, 200-250 ms of duration) identified as the time interval between the minimum and the maximum knee angle values (see the Figure).
The following parameters were calculated: the maximum flight time (MFT, ms) as the maximum value obtained during the test; the rate of change of FT (rcFT, ms/jump) as the slope of the linear regression among the FTs calculated during the test; the initial value and the rate of change of: average rectified value (ARV, μV), mean frequency of the power spectrum (MNF, Hz), and muscle fiber conduction velocity (CV, m/s).
RESULTS: Three different phases were clearly distinguishable combining EMG and goniometer signals: the concentric (CP), the flight and the eccentric phases (EP). MFT was found to correlate with: rcFT ($r=-0.72$, $p<0.01$), MNF intial value ($r=0.61$, $p<0.05$), and CV initial value ($r=0.59$, $p<0.05$).
MNF initial value was found to correlate with CV initial value ($r=0.61$, $p<0.05$), whereas rcFT was found to correlate with CV rate of change ($r=0.58$, $p<0.05$).
CONCLUSIONS: Our data show that: 1) it is feasible to properly record EMG signals during continuous jumping and 2) MNF and CV are the EMG variables correlating with mechanical data. Hence, surface EMG recording can be adopted as an additional approach to muscular functional evaluation during the continuous jumping test.

The figure shows sEMG signals recorded from the electrode array during the concentric (CP), the FLIGHT and the eccentric (EP) phases triggered by the electrogoniometer (the signal in the bottom)

ACQUISITION AND ANALYSIS OF OLYMPIC KAYAK INDOOR PADDLING

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AIMS: Aim of the work was the biomechanical analysis of elite female olympic kayak athletes during indoor paddling on ergometers in order to help trainers to define suitable functional evaluation methods.
METHODS: An integrated motion capture system was used for the study of 5 elite female athletes from Italian National team. Paddle trajectory, trunk and limbs motion and forces developed by the athletes on a dynamometric footpad were recorded. Several quantitative biomechanical parameters were correspondently defined. Symmetry and regularity criteria were adopted to define a skill classification for each analysis parameter and final correlation with sport results classification was investigated.
RESULTS: Kinematic and kinetic data were analysed following different criteria in order to look for the possible correlation between different quantitative biomechanical parameters and the athletes ranking: the first analysis criteria was based on the paddle motion: the paddle trajectory was plotted in the transverse plane XZ and in the frontal plane ZY. The second comparative parameter was the relative angle between shoulder and pelvis, named θsp. It was supposed to be preferably low and symmetric, indicating rotation of shoulders about pelvis. Third data analysis regarded the motion of the Great Trochanters (GT) in the sagittal plane XY: the two sides symmetry and the minor amount of elevation in the Y direction of the GT from the seat were considered correlated to a good technique. Fourth analysis focused on the range of flexion angles φL and φR at the two knees: symmetry between the two legs were researched. Finally, the two normal forces applied to the footpad FNL and FNR were investigated and again evaluated in terms of symmetry between the two sides.
CONCLUSIONS: The paddle motion analysis showed how best athletes were able to perform a symmetric, steady and compact trajectory in the XZ plane. The analysis of angle θsp revealed how testers 1 and 4 were able to produce a compact symmetric trunk rotation. Motion analysis of GT at the two sides exhibited best results for tester 1, with highest symmetry and lowest ΔY. The footpad force analysis showed best symmetry for tester 1 and worst for tester 2: they were anyway the only testers able to increase the forces at increased pace.
All athletes, despite their national or international ranking, showed aspects of the paddling technique that may be improved and that were revealed by the present analysis.

Definition of relative angle θsp between shoulders and pelvis

MICROGRAVITY INDUCED CHANGES IN THE CONTROL OF MOTOR UNITS

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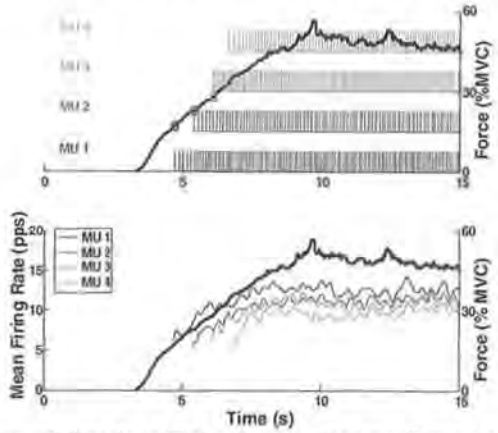
AIMS: The understanding of the neuromuscular basis for microgravity-induced degradation in motor function is essential for the educated design of exercise programs to counter the effects of microgravity as well as identify and validate ground-based models for the phenomenon. The goal of this project is to understand the effects of microgravity on the control of muscles by investigating the regulation of the firing activity of motor units that make up a muscle. The following specific aims are being investigated: 1) Understand the effects of microgravity on the control of motor units, 2) Compare the effects of microgravity on two muscles that are used to varying extents in space, in order to assess the potential of muscle use to curtail microgravity-induced disturbances in control properties of motor units, and 3) Determine the course of recovery after re-exposure to Earth gravity.
METHODS: Short duration (Space Shuttle) crewmembers serve as subjects in two general sets of procedures performed both pre-flight and post-flight. Multichannel Intramuscular electromyographic (iEMG) signals are recorded from a hand muscle, the First Dorsal Interosseous, and a knee extensor muscle, the Vastus Medialis (VM). All iEMG recordings are taken while subjects trace specified Force trajectories displayed on a computer screen. The iEMG data are decomposed into motor unit firing trains using the Precision Decomposition II system. The resulting firing trains are analyzed to detect modifications in the control of the recruitment and firing rate behavior of motor units.
RESULTS: To date, we have successfully collected force and iEMG data in 1 astronaut on three days prior to launch [-120, -119, and -116] and four days following return after 14-days in space [+0, +1, +3, +7, +13]. The iEMG signals were of high quality and decomposable, typically yielding 4-5 motor unit trains per contraction. Figure shows the the decomposition results for one contraction performed at 50% of the maximum voluntary contraction (MVC) level on landing day. Note the orderly recruitment and layering of firing rates, both of which were also observed in the pre-Flight data. Preliminary analysis, however indicates an increased variability of firing rates and force output immediately upon return to earth.
CONCLUSIONS: We are currently analyzing the motor unit recruitment and firing rates as well as the cross-correlation among mean firing rates of pairs of motor units from these data. attention will be directed at comparing these results to similar data obtained by us from elderly subjects, to verify whether the effects of microgravity on muscle is similar to that of aging.



Motor unit firing times (Top) and mean firing rates (Bottom) of 4 motor units from the VM muscle on landing day. They are superimposed on the contraction force and plotted with respect to time

This project was funded by NASA Grant No.99E192

PHASIC TRUNK MUSCLE ACTIVITY AFTER BED-REST: IMPLICATIONS FOR LUMBO-PELVIC STABILISATION. PART OF THE EUROPEAN SPACE AGENCY BERLIN BED-REST STUDY: FEB 2003 - MAY 2005

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AIMS: Motor control dysfunction of the lumbo-pelvic musculature in low back pain (LBP) is well documented. It has been suggested that sedentary lifestyle habits in western countries be associated with a higher incidence of LBP. Bed-rest is a model useful for exaggerating long-term neuromuscular changes that may be associated with inactivity and sedentarism. In this study we wished to apply a novel method of quantifying tonic (continuous) versus modulating (burst-like) muscle activity during movement as a measure of motor control in the lumbo-pelvic musculature. This motor control parameter was examined during 8-weeks of bed-rest and a 1-year follow-up period.
METHODS: 20 subjects took part in a 8-week bed-rest study with 1-year follow-up at the Universitätsklinikum Benjamin Franklin, Berlin, Germany. Ten received a vibration exercise countermeasure. Subjects were tested at regular intervals during and after bed-rest. The electromyographic activity external and internal oblique (EO and IO) and medial and lateral lumbar erector spinae (MLES and LLES) was measured during a standard motor task of the lower limb at five different speeds. EMG data was high-pass filtered, rectified and the low pass filtered to give a "linear envelope". Significant maxima and minima were detected and a ratio of the two calculated (phasic-tonic ratio - PTR). Data were pooled across time to give "date clusters": baseline, early bed-rest, late bed-rest, early follow-up and late follow-up. Root-mean-square (RMS) acitivity of the raw EMG data was also measured.
RESULTS: Significant effects were detected for the LLES, MLES and IO. IO's PTR was significantly increased at early bed-rest ($p=0.041$), mid-late bed-rest ($p=0.048$), early follow-up ($p=0.018$) and mid-late follow-up ($p=0.004$). MLES and LLES measures were increased at mid-late follow-up ($p=0.003$ and $p=0.007$ respectively). Analysis showed a strong positive correlation between RMS activity and PTR value in all muscles ($p<0.001$). No significant difference was observed over time between the vibration training and non-training subjects.
CONCLUSIONS: The results indicate that the muscles behaved in a more phasically modulated, burst-like, fashion. IO did so from early in bed-rest through to the end of the study period (up to 1 year later), MLES and LLES did so by the end of this time period. This may indicate the development of short-term (in IO) and long-term (IO, MLES, LLES) motor control dysfunction in the bed-rest subjects. The strong correlation between the PTR measure and activity measures suggests the development of muscle overactivity in those muscles during and after bed-rest. These findings may have implications for long-term motor control changes associated with sedentary lifestyle.

EVALUATION OF TORQUE-ASSISTED BICYCLES BY MUSCULAR ACTIVITY AND AUTONOMIC REGULATION

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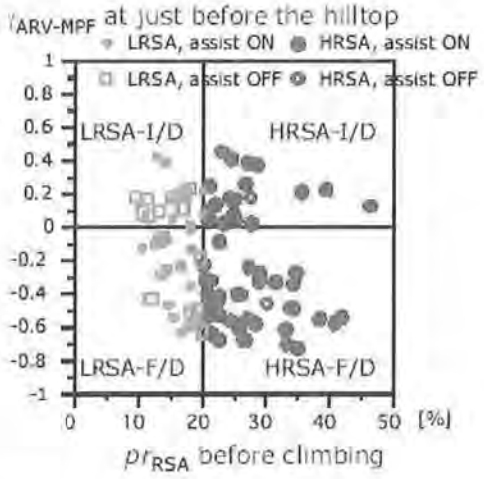
2) Yamaha Motor, Niigata, Japan

AIMS: Torque-assisted bicycles (TABs) support rider-generated torque with electric power from the beginning of cycling up to a

predetermined speed. While facilitating voluntary movement and supporting muscle force under muscular fatigue is a practical objective, current TABs are not well designed to take into account physical activity. Thus, our final goal is to design the customized assistance based on varying individual physical activity and vehicle data from the TAB.

METHODS: We have found two interesting states in the time-varying behavior of pr_{RSA}, the RSA (Respiratory Sinus Arrhythmia)-related power ratio. One was a large fluctuation in the R-R interval before and after climbing, especially during rest periods, with a high percentage in pr_{RSA} (HRSA) before climbing. The other was a low percentage in pr_{RSA} (LRSA) before climbing with little fluctuation in the R-R interval before and after climbing. The condition for HRSA was "averaged pr_{RSA} before climbing ≥20%." The threshold was determined based on the median (21.3%) of pr_{RSA} estimated from 103 trials. To categorize physical activity during cycling, we further added an index of muscle activity by the correlation coefficients between ARV and MPF, $\gamma_{ARV\text{-}MPF}$, during consecutive 5 strokes just before the hilltop. Thus four groups appeared in a scatter graph between pr_{RSA} before climbing and $\gamma_{ARV\text{-}MPF}$ just before the hilltop. We evaluated in which group the torque-assist was the most effective.

RESULTS: Figure shows the scatter graph of pr_{RSA} before climbing and $\gamma_{ARV\text{-}MPF}$ just before the hilltop during climbing. Samples varied significantly in pr_{RSA} over consecutive phases for the positive region of $\gamma_{ARV\text{-}MPF}$. Other indices such as $\gamma_{ARV\text{-}torque}$ or the MPF difference at a stroke did not demonstrate this behavior. The percentage of assist-off trials was the highest in LRSA-I/D and the lowest in HRSA-I/D. Note that the percentage of assist-off trials in LRSA was higher than that in HRSA. The HRSAF/ D, the largest number of trials, showed muscular fatigue: even in HRSA with assist-on trials muscular fatigue sometimes occurred. In this group, the speed was medium and the torque was the lowest. On the other hand, muscular fatigue appeared in the same way, but LRSA emerged for LRSA-F/D. Besides, the speed was the lowest and the torque was medium. In the LRSA-I/D, the speed was close to that of the HRSA-F/D and the torque was larger than those of the HRSA-F/D and LRSAF/D. However, the large torque did not tightly link to the strength of muscle activity. The muscle activity sufficiently linked to the torque and muscular fatigue did not appear with enough autonomic regulation for the HRSA-I/D. Contrary to expectation, the torque-assist supported HRSA state, but it was sometimes not enough for muscle activity.



Scatter graph of pr_{RSA} before climbing and $\gamma_{ARV\text{-}MPF}$ just before the hilltop

CONCLUSIONS: We showed the variation of physical activity during cycling with the torque-assisted bicycle. The results showed that muscular fatigue and autonomic regulation should be evaluated separately. Accordingly, torque-assist would be first effective for the group under not enough autonomic regulation (LRSA-F/D).

FORCE CAPACITY MEASURES PREDICT FALL OUTCOME IN THE ELDERLY

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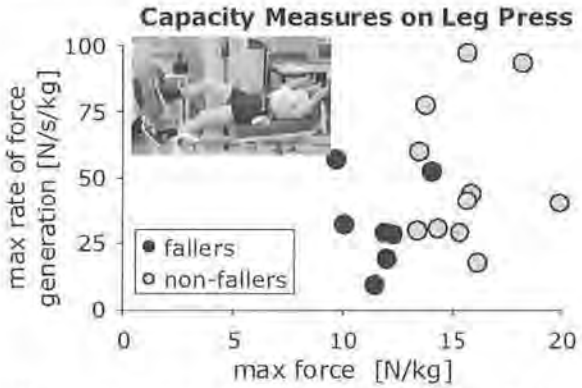
AIMS: For effective fall prevention in the elderly, training programs should focus on those people who have a high risk of falling. To identify high-risk fallers, we can use our knowledge on factors that are related to falls. Tripping over an obstacle is one of the main causes for falls in the elderly. From experimental studies on tripping reactions, we found that older fallers generated lower maximum moments around the ankle and adapted moments around all lower extremity joints at a lower rate during the push-off phase of balance recovery [1]. During the landing phase, high knee extension moments have to be generated. The aim of this study was to search cross-sectionally for force generating capacity measures that can predict fall outcome in older adults.

METHODS: Eighteen healthy older adults (11 women, 71 ± 4.6 years) participated. All subjects performed a series of maximum force generating capacity measures: static ankle plantar flexion capacity and knee extension capacity in a dynamometer and dynamic push-off during jumping and in a leg press fitness apparatus. The maximum force and the rate of change in force over the first 100 ms after force onset were calculated, relative to body mass. Furthermore, the subjects' capacity to recover balance after tripping was measured experimentally. In about 5 of 40 walking trials, subjects were tripped over an obstacle that suddenly appeared from the floor. Subjects wore a safety harness. They were classified as fallers based on full use of the harness in at least 2 tripping trials. A statistical stepwise discriminant analysis was used to find the best predictor(s) for falls and to quantify the predictive value.

RESULTS: Seven older adults were classified as fallers. Preliminary analysis indicated that the maximum force produced on the leg press was the variable best discriminating between fallers and non-fallers. Based on this measure, 86% (6 out of 7) of the fallers and 100% of the non-fallers were classified correctly. Figure presents the leg press capacity outcome for fallers and non-fallers.

CONCLUSIONS: Maximum capacity to generate a push-off force by the whole leg in a squat leg press is related to balance recovery capacity. Although all force producing capacity measures in this study were strongly correlated, this measure appeared to result in the best classification of older fallers and nonfallers. Identification of fallers might be refined to allow selection of elderly people that can benefit most from strength training to prevent falls.



Maximum capacity on the leg press for fallers and non-fallers.

[1] M. Pijnappels, M.F. Bobbert, J.H. van Dieën. Gait & Posture (2005) 21:388-394.

EFFECT OF ALTERED LOCAL TEMPERATURE ON FORCE STEADINESS IN YOUNG AND OLDER WOMEN

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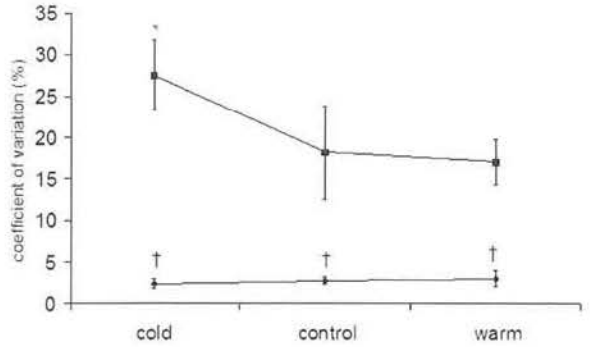
AIMS: One of the main characteristics of ageing is the reduced capability of adapting to modifications of either the internal or the external environment. Since temperature is known to have substantial effects on the neuromuscular system, the purpose of the study was to investigate the effects of altered muscle temperature on the ability to exert a precise force during low level isometric contractions of the dorsiflexor muscles in young and older women.

METHODS: 15 young (age, mean±SD, 24±3 yr) and 11 older (68±7 yr) healthy women performed three submaximal isometric contractions of the dorsiflexor muscles at 5%, 10%, and 15% of the maximal voluntary contraction (MVC) force for 30 s. The force trace was displayed on a computer screen to provide participants with visual feedback. The three contractions were performed at normal muscle temperature and with cooling and warming of the lower leg by ~4 °C. Muscle temperature was measured from the tibialis anterior muscle with a flexible intramuscular probe (Ellab Ltd, Copenhagen, Denmark) inserted ~1 cm into the muscle at a 45° angle in the direction of the muscle fibres. The coefficient of variation (CofV) and the relative power in the frequency bands 0-3 Hz (low), 4-6 Hz (middle), and 8-12 Hz (high) were computed from the force signal to characterize steadiness. For single motor unit recording, intramuscular EMG signals were recorded with two wire electrodes made of Teflon coated stainless steel (A-M Systems, Carlsborg,WA, USA), inserted into the muscle with a 23 G needle. Data (shown as mean ± SE) were analysed using a three-way (age x temperature x contraction force) repeated measures ANOVA with post-hoc pair-wise comparisons (Student-Newman-Keuls test) where appropriate.

RESULTS: A different response to temperature was observed between the young and older subjects. The younger subjects had a consistent CofV for the three temperatures (2.4±0.5%, 2.8±0.4%, 3.0±1.0%, for cold, control, warm, respectively), while the older subjects showed increased CofV with cooling compared to the control and warm conditions (27.5±4.3%, 18.1±5.7%, 17.0±2.7%, respectively; P<0.05)).
In both groups, the relative power in the low frequency band decreased with temperature (young: 88.9±0.5%, 87.2±0.8%, 84.3±0.8%; older: 90.6±0.9%, 85.7±1.4%, 83.9±2.3%) (P<0.05). For the young but not for the older, the relative power in the high frequency band increased with temperature (1.9±0.1%, 2.8±0.4%, 3.9±0.5%) (P<0.05). Motor unit discharge rate and interpulse interval did not change with temperature for both groups.

CONCLUSIONS: Cooling affected the steadiness in the older group only. Motor unit discharge properties were not responsible for this difference between groups, suggesting a role of the stretch reflex loop. The different response to temperature of the relative power of force in the high frequency band between groups supports this hypothesis.

Marie-Curie Fellowship of the European Community program "Marie Curie Training Sites" (HPMT-CT-2000-00092)



*Coefficient of variation of force as a function of temperature for the young (◆) and older group (■). * denotes significantly different from control and warm (P<0.05). † denotes significantly different to older group (P<0.05)*

T17.P01
THE INFLUENCE OF BODY POSITION ON MUSCLE RECRUITMENT DURING CYCLING IN NOVICE AND ELITE CYCLISTS

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AIMS: Trained cyclists are better able than novice cyclists to maintain cycling efficiency in a range of riding positions, which involve different orientations of the upper body. The mechanisms by which orientation of the upper body influences cycling efficiency are not well understood. We suggest that changes in muscle recruitment may be one mechanism by which body position influences efficiency. This study investigated the influence of upper body orientation on leg muscle recruitment during cycling in novice and highly trained cyclists.
METHODS: Participants were ten novice and nine highly trained cyclists. Two experimental conditions of cycling in an upright riding position (i.e. grasping brake hoods) and an aerodynamic riding position (i.e. grasping drops bars) were investigated. Electromyographic (EMG) recordings were made with intramuscular fine-wire electrodes from tibialis anterior (TA), tibialis posterior (TP), peroneus longus (PL), gastrocnemius lateralis (GL) and soleus (SOL) muscles.
RESULTS: In trained cyclists, the aerodynamic riding position, when compared to the upright riding position, was associated with greater variability of TP (root mean square error (RMSE) 4.7±1.9% increase) PL (6.1±2.1% increase) and SOL (6.9±2.2% increase) recruitment but less variability of TA recruitment (7.1± 2.7% decrease). In contrast, riding position had no influence on variability of muscle recruitment in novice cyclists, but variability of novice cyclists' muscle recruitment was more than that of trained cyclists in both riding positions. Body position did not effect other parameters of muscle recruitment (i.e. timing and amplitude) in either group.
CONCLUSIONS: Our results indicate that orientation of the upper body alters aspects of leg muscle recruitment, specifically the variability of muscle recruitment, which may influence cycling efficiency. Increased variability of leg muscle recruitment in trained cyclists may influence cycling efficiency and may be interpreted as a decreased ability of the central nervous system to reproduce the desired pattern of muscle recruitment. Regardless of how recruitment variability is interpreted, body orientation influenced recruitment and thus our results contradict the hypothesis that trained cyclists are better able to maintain muscle recruitment, and possibily cycling efficiency, between upright and aerodynamic positions. Variability of recruitment of muscles acting only at the ankle was influenced by orientation of the upper body, which suggests involvement of neurophysiological, and not only biomechanical, mechanisms. This is consistent with evidence of neurophysiological influences of proximal body orientation on limb movement from studies of the influence of head and neck orientation on upper limb movement. The effect of upper body orientation on lower limb kinematics also requires investigation. The effect of body position on variability of leg muscle recruitment in trained cyclists may also be the result of training adaptations. Trained cyclists typically spend less than ten percent of their time in the aerodynamic position. The increase in variability of muscle recruitment when in the aerodynamic riding position may be associated with the cyclists moving from a very familiar riding position (upright position) to a less familiar position (aerodynamic position), which would be consistent with previous findings of increased variability in novel movement.

T17.P02
THE INFLUENCE OF CYCLING CADENCE ON LEG MUSCLE RECRUITMENT IN NOVICE AND HIGHLY TRAINED CYCLISTS

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AIMS: There has been considerable debate regarding the relationship between muscle recruitment, cadence and cycling experience. This relationship provides insight into the mechanisms of movement control and may provide further explanation for the selection of high cadences by trained cyclists. This study investigated and compared the relationship between muscle recruitment and cadence in novice and highly trained cyclists.
METHODS: Intramuscular electromyographic (EMG) recordings were made using indwelling fine-wire electrodes from tibialis anterior (TA), tibialis posterior (TP), peroneus longus (PL), gastrocnemius lateralis (GL) and soleus (SOL) muscles. Four experimental conditions of cycling at individual preferreed cadence (i.e. self selected cadence), 55-60, 75-80 and 90-95 rpm for 3 min were investigated in random order, following a 7 min warm up. Each experimental period consisted of 2 min of acclimatization and 1 min of data capture. Cycling trials were conducted on each participant's bike secured on a magnetic trainer. Cycling intensity was controlled using ratings of perceived exertion (RPE).
RESULTS: Peak EMG amplitude of each muscle increased in a linear manner with the increase in cadence from 57.5 to 92.5 rpm in both novice or highly trained cyclists. Cadence did not influence times of EMG onset, peak activity or offset between muscles in either group. Peak EMG amplitude was not different at individual preferred cadence in either group. EMG modulation (i.e. the ratio of the amplitude of secondary muscle activity to the amplitude of muscle activity in the primary burst, and secondary EMG duration) decreased with increasing cadence in novice cyclists but was not influenced by cadence in highly trained cyclists.
CONCLUSIONS: Our data suggest that preferred cadence is not related to peak EMG amplitude as peak amplitude increased linearly with cadence and was not minimized at preferred cadence in either novice or highly trained cyclists. However, increases in the duration of primary muscle activity (i.e. decreased secondary EMG duration), the relative amplitude of secondary muscle activity and muscle coactivation with increases in cadence in novice cyclists may reflect less developed control of the movement. These changes in muscle recruitment may be related to the tendency for novice cyclists to select lower cadences.

T17.P03
A WIRELESS INSTRUMENTED PEDAL TO MEASURE FORCE DURING CYCLING

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AIMS: In sports, the assessment of task execution and the programming of training procedures can take great advantage by the use of instrumented devices. In fact, the availability of numeric indexes can integrate the functional evaluations made by sport trainers. Following this rationale, this work deals with the design of an instrumented pedal for bikes providing the force components exerted during pedalling. In particular the pedal has been developed to measure two force components, i.e. the perpendicular to the load plane and the tangential toward the motion direction. The knowledge of the dynamic of the task can improve the whole performance by providing insights on training programs and postural modifications to sport trainers.
METHODS: The hardware consist in an instrumented pedal designed with the same features of a commercial pedal. The pedal is equipped with a commercial clipless coupling compatible with SPD™ cleats (Shimano Pedaling Dynamics). The measurement of both force components exerted on the pedal is made possible by using a specially designed strain gauge based load cell, fixed between the clipless coupling and the pedal frame. Strain gauges are connected in two full Wheatstone bridge configurations that are completed using a dedicated strain gauge amplifier. In order to obtain the relative rotational angle between

the pedal and the crank, a linear single-turn precision potentiometer is placed between the pedal frame and the pedal spindle. The signals are acquired using a specially designed circuit based on PIC microcontroller (Microchip PIC18LF252), making the A/D conversion. Digital data are wireless sent to a remote PC by a Bluetooth™ transmitter integrated on the previous circuit.

RESULTS: The pedal was calibrated using defined load, in order to obtain a calibration matrix for the two force channels. The potentiometer signal presents a linear relationship between the electrical output and the angular displacement of the pedal.
Some preliminary acquisitions were made using a 8-bit conversion and a sample frequency of 1440 Hz for each channel. Data of calibrated forces and angular displacements are shown in Fig.1. Time trends are in agreement with previous woks on pedal forces analysis [1]. The data for each pedalling cycle show different force profiles in the phases of pushing (0°-180°) and pulling (180°-360°).

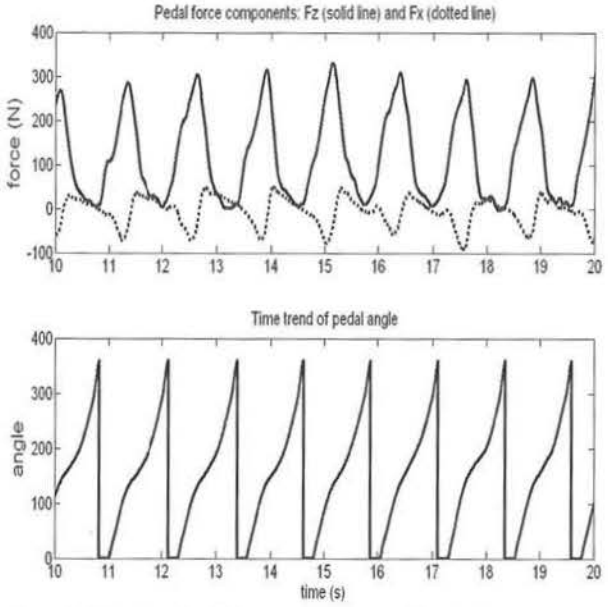

Figure 1: Time trend of force components and angle displacement.

CONCLUSIONS: Data analysis carried on applied forces during pedalling is useful to evaluate the execution strategy for the task and to assess the efficiency of pedalling. It is important to remark that the measured force components and the angle time trend can be used to obtain the force components on the crank reference system. This information can be used to evaluate the percent of resultant applied force used for the application of efficient torque to the bicycle crown. In this way it is possible to define an efficiency index of pedalling to evaluate the performance.

[1] Sanderson D. J., Black A., "The effect of prolonged cycling on pedal forces", J. Sport Sciences, 2003, 21: 191-199.

T17.P04
RELIABILITY OF ELECTROMYOGRAPHY IN COUNTER-MOVEMENT JUMPING

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AIMS: The fundamental basis of all electrophisiological analysis is without a shadow of a doubt the analisys of excitable cells and their corresponding action potentials. In this way the inherent reliability of the data obtained struggles to achieve it's main goal of maximally removing assessment error. Hence mandatory reliability validation is required to ensure data comparison liability. The main purpose of our study was to assess the intraclass reliability of selected EMG variables in counter-movement jumping (CMJ). In this way we aimed to verify the reliability of surface electromyography in high speed body-segment movements, without electrode removal after one hour rest, as well as with electrode removal after a one week resting period.

METHODS: In order to achieve this purpose we assessed a group of 8 subjects (4 male and 4 female). We focussed on the analysis of the Average EMG full wave rectified signal, it's iEMG and the corresponding root mean square. This analysis was performed using surface electrodes (BlueSensor, Medicotest) and concerned the lower limb's vastus lateralis, vastus medialis, internal gastrocnemius, external gastrocnemius and biceps femoris muscles. Thus in order to evaluate CMJ reliability subjects performed two CMJ one hour apart from each other without electrode removal and two CMJ one week apart with electrode removal. For statistical validation we used the intra-class correlation coefficient in all variables.

RESULTS and CONCLUSIONS: Our results demonstrated that all selected EMG variables revealed high reliability both with (ICC values between 0.74 and 0.92) and without electrode removal (ICC values between 0.90 and 0.98). Although the values obtained with electrode removal were slightly lower but still strongly reliable. Flight time values were also highly reliable contributing for the validation of jump comparison between different assessments. Hence our results apparently demonstrated that CMJ EMG analysis is liable as well as highly reliable with and without electrode removal.

CM Jumping		Without Electrode removal					With electrode removal				
		Before		After			Before		After		
		Mean	SD	Mean	SD	ICC	Mean	SD	Mean	SD	ICC
Avg	VL	0,394	0,150	0,386	0,125	**0,97**	0,389	0,124	0,405	0,119	**0,93**
	VM	0,355	0,087	0,361	0,089	**0,94**	0,358	0,091	0,389	0,099	**0,80**
	GI	0,166	0,078	0,166	0,073	**0,93**	0,171	0,080	0,194	0,073	**0,92**
	GE	0,164	0,063	0,148	0,054	**0,93**	0,148	0,055	0,181	0,101	**0,75**
	BF	0,083	0,031	0,080	0,028	**0,97**	0,080	0,028	0,081	0,029	**0,91**
iEMG	VL	0,330	0,152	0,324	0,139	**0,99**	0,324	0,139	0,315	0,098	**0,82**
	VM	0,290	0,070	0,296	0,067	**0,95**	0,290	0,070	0,304	0,067	**0,86**
	GI	0,134	0,065	0,136	0,063	**0,95**	0,138	0,063	0,151	0,056	**0,92**
	GE	0,131	0,047	0,120	0,040	**0,95**	0,120	0,041	0,141	0,077	**0,78**
	BF	0,069	0,022	0,065	0,020	**0,97**	0,065	0,020	0,063	0,022	**0,93**
RMS	VL	0,575	0,196	0,564	0,178	**0,98**	0,573	0,184	0,656	0,175	**0,69**
	VM	0,503	0,137	0,505	0,137	**0,96**	0,499	0,136	0,610	0,195	**0,77**
	GI	0,278	0,133	0,284	0,136	**0,87**	0,294	0,149	0,341	0,139	**0,92**
	GE	0,271	0,109	0,236	0,095	**0,92**	0,238	0,097	0,285	0,172	**0,78**
	BF	0,154	0,072	0,129	0,072	**0,93**	0,134	0,067	0,159	0,074	**0,89**
Avg/t	VL	0,475	0,153	0,464	0,113	**0,95**	0,471	0,115	0,495	0,135	**0,91**
	VM	0,434	0,122	0,443	0,125	**0,91**	0,441	0,125	0,478	0,128	**0,86**
	GI	0,205	0,101	0,203	0,092	**0,93**	0,213	0,105	0,241	0,100	**0,88**
	GE	0,204	0,086	0,183	0,073	**0,93**	0,185	0,075	0,229	0,140	**0,74**
	BF	0,101	0,042	0,099	0,036	**0,97**	0,099	0,036	0,103	0,041	**0,91**
iEMG/t	VL	0,395	0,151	0,386	0,129	**0,97**	0,390	0,129	0,668	0,222	**0,76**
	VM	0,351	0,089	0,363	0,092	**0,93**	0,356	0,094	0,371	0,086	**0,90**
	GI	0,163	0,081	0,166	0,076	**0,94**	0,170	0,079	0,186	0,075	**0,89**
	GE	0,160	0,067	0,148	0,052	**0,93**	0,149	0,054	0,178	0,104	**0,74**
	BF	0,085	0,030	0,081	0,025	**0,94**	0,081	0,025	0,078	0,029	**0,92**
TV		0,490	0,054	0,490	0,051	**0,98**	0,491	0,053	0,485	0,056	**0,98**
DF		0,825	0,066	0,823	0,062	**0,90**	0,815	0,065	0,819	0,074	**0,90**

Mean, Standard Deviation (SD) and ICC of Flight time (FT), phase duration (DF) as well as EMG variables recorded in CMJ from VL,VM,GI,GE and BF muscles, with and without electrode removal.

T17.P05
ELECTROMYOGRAPHIC ANALYSIS OF COUNTER-MOVEMENT JUMPING - A COMPARATIVE STUDY BETWEEN DIFFERENT TARGET JUMPING HEIGHTS

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AIMS: The existing knowledge about surface electromyography

has considerably evolved over time, having mostly developed in the human movement studies, essentially focussing on the analisys of neural phenomena implied in movement control as well as in it's mechanical outputs. This technique is revealing itself as a major tool in movement studies based in the sports domain. Our main goal was to compare EMG signal amplitude regarding Counter-Movement jumps performed to different target jumping heights (20, 40 and 60 cm respectively).

METHODS: For this purpose we gathered a sample of 8 subjects (4 male and 4 female), who were assessed using surface electrodes (BlueSencor, Medicotest) placed over the lower limb's vastus lateralis, vastus medialis, internal gastrocnemius, external gastrocnemius and biceps femoris muscles.

We focussed on the analysis of the Average EMG full wave rectified signal as well as in it's iEMG. Thus in order to evaluate CMJ EMG amplitude subjects performed two jumps for each predefined height. Each jump was further analyzed in regard to it's eccentric and concentric phase (this division was made bearing in mind data colected from the force platform also used).

		Eccentric Phase					
		Altura de 20cm		Altura de 40cm		Altura de 60cm	
		Mean	SD	Mean	SD	Mean	SD
AvgEMG (mV)	Vl	0.24	0.15	0.27	0.14	0.30	0.21
	Vm	0.25	0.09	0.29	0.12	0.28	0.11
	Gi	0.13	0.08	0.20	0.16	0.10	0.05
	Ge	0.13	0.06	0.15	0.09	0.09	0.04
	Bf	0.05	0.02	0.10	0.08	0.08	0.07
iEMG (mV)	Vl	0.10	0.05	0.11	0.05	0.13	0.07
	Vm	0.10	0.05	0.11	0.04	0.12	0.04
	Gi	0.06	0.03	0.07	0.05	0.04	0.02
	Ge	0.05	0.02	0.06	0.03	0.04	0.02
	Bf	0.02	0.01	0.04	0.03	0.03	0.02
AvgEMG/ Δt (mV.s)	Vl	0.67	0.47	0.72	0.42	0.74	0.73
	Vm	0.67	0.31	0.77	0.41	0.70	0.41
	Gi	0.40	0.31	0.54	0.51	0.25	0.16
	Ge	0.38	0.23	0.42	0.34	0.22	0.15
	Bf	0.13	0.07	0.27	0.23	0.19	0.19
iEMG/Δt (mV.s)	Vl	0.26	0.16	0.27	0.14	0.30	0.20
	Vm	0.26	0.12	0.29	0.12	0.28	0.11
	Gi	0.16	0.13	0.19	0.16	0.10	0.05
	Ge	0.14	0.08	0.15	0.09	0.08	0.05
	Bf	0.05	0.02	0.10	0.08	0.08	0.06
Phase Duration		0.41	0.13	0.40	0.08	0.44	0.10

		Concentric Phase					
		Altura de 20cm		Altura de 40cm		Altura de 60cm	
		Mean	SD	Mean	SD	Mean	SD
AvgEMG (mV)	Vl	0.21[a]	0.16	0.40	0.23	0.60[b]	0.20
	Vm	0.14[a]	0.08	0.31[b]	0.11	0.51[ab]	0.26
	Gi	0.28	0.22	0.38	0.20	0.51	0.28
	Ge	0.23[a]	0.10	0.34	0.12	0.45[a]	0.18
	Bf	0.18[a]	0.07	0.26	0.12	0.37[a]	0.25
iEMG (mV)	Vl	0.03[a]	0.03	0.07	0.05	0.15[a]	0.48
	Vm	0.02[a]	0.01	0.05[b]	0.02	0.12[ab]	0.06
	Gi	0.04[a]	0.04	0.06[b]	0.04	0.12[ab]	0.06
	Ge	0.03[a]	0.02	0.06[b]	0.02	0.10[ab]	0.05
	Bf	0.02[a]	0.01	0.04	0.02	0.09[a]	0.06
AvgEMG/ Δt (mV.s)	Vl	1.30[a]	0.91	2.26	1.09	2.62[a]	0.89
	Vm	0.92[a]	0.50	1.81	0.60	2.25[a]	1.17
	Gi	1.84	1.38	2.12	1.15	2.25	1.22
	Ge	1.54	0.80	2.04	0.85	1.97	0.70
	Bf	1.08	0.53	1.60	0.81	1.61	1.05
iEMG/Δt (mV.s)	Vl	0.21[a]	0.16	0.40	0.24	0.59[a]	11.31
	Vm	0.14[a]	0.09	0.32	0.11	0.50[a]	0.26
	Gi	0.29	0.22	0.37	0.20	0.51	0.27
	Ge	0.21[a]	0.11	0.35	0.12	0.44[a]	0.18
	Bf	0.16[a]	0.07	0.25	0.12	0.37[a]	0.25
Phase Duration		0.15[a]	0.03	0.17[b]	0.02	0.23[ab]	0.03

Mean, Standard Deviation (SD) and independent samples t-test for phase duration (DF) as well as EMG variables recorded in CMJ from VL,VM,GI,GE and BF muscles.
a - Statistically significant differences between 20 and 40cm para um P<0,05; b - Statistically significant differences between 20 and 40cm para um P<0,05; c - Statistically significant differences between 20 and 40cm para um P<0,05

For statistical analysis we used the independent samples t-test in order to compare performance means between jumping heights.

RESULTS and CONCLUSIONS: Our results demonstrated a progressive increase in muscle EMG activation along with an increase in jumping height. The concentric phase revealed itself as the most relevant, displaying values signifficantly different from each other.

We may thus conlude that with a progressive increase in target jumping height there is also a simultaneous gradual increase in neuromuscular activity even though these were balistic and extremely high-speed segment displacements.

T17.P06
RELATIONSHIP BETWEEN EMG AND MUSCLE OXYGENATION IN SYNERGYSTIC MUSCLES DURING DYNAMIC MUSCLE ACTION

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AIMS: The purpose of present study was to clarify the heterogeneity of synergist muscles in relationship between muscle electrical activity and muscle oxygenation during dynamic muscle action.

METHODS: Subjects were five healthy males. They were asked to sit quietly for more than 3 min as a control period. Then they stood up and performed 4 s bilateral calf-raise consisted of 2 s heel up phase and 2 s heel down phase. They repeated the calf-raise 20 times leaded by an electric metronome. Surface electromyogram (EMG) was recorded from medial and lateral gastrocnemius (MG and LG) and soleus (SOL) in right leg using bipolar electrode (SX-230, DKH, Japan). To estimate the oxygenated hemoglobin and myoglobin (O_2Hb/Mb), deoxygenated hemoglobin and myoglobin (HHb/Mb), total hemoglobin and myoglobin (cHb/Mb) content and tissue oxygenation index (TOI) in target muscles, two channels optical probes NIRS were firmly placed on the skin surface of muscle bellies (NIRO-200, Hamamatsu Photonics, Japan). Firstly, MG and LG muscles were measured at once, and MG and SOL muscles were measured using the same protocol. O_2Hb/Mb, HHb/Mb and cHb/Mb were expressed as changes from rest values, and TOI was expressed as a percentage (%). The change of ankle joint angle was measured using an electric goniometer (SG110/A, DKH, Japan). The data of EMG, NIRS and joint angle were stored on a personal computer by using an analog-to-digital converter (PowerLab/16sp, ADInstruments).

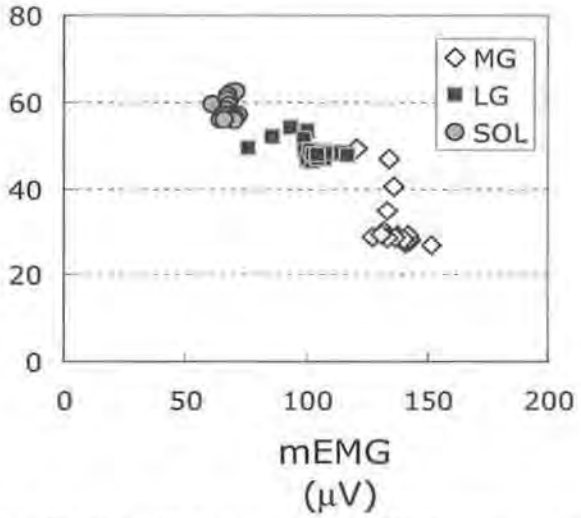

Fig.1: The relationship between mEMG and TOI (tissue oxygenation index) in triceps surae.

RESULTS: The mean amplitude of EMG (mEMG) increased greater in MG than in LG at the first half of the action, though mEMG of SOL did not show significant increase and kept the almost constant value during exercise. O_2Hb/Mb decreased, and HHb/Mb increased in all three muscles during the exercise. The greatest change was observed in MG.
The relationships between mEMG and TOI were different among three muscles (Fig.1).
CONCLUSIONS: The results of this study showed the different relationship between EMG and muscle oxygenation in triceps surae during calf-raise. This might be due to the difference in muscle activation, fiber composition and muscle architecture.

This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Young Scientists (B) 16700473, 2005.

T17.P07
TIMING OF ELECTROMYOGRAPHIC ACTIVITY OF ANKLE MUSCLES IN VOLLEYBALL PLAYERS WITH FUNCTIONAL ANKLE INSTABILITY

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AIMS: The purpose of this study was to determine if volleyball players with functional ankle instability (FI) shows differences in muscle onset latencies for peroneus longus (PL), tibialis anterior (TA) and gastrocnemius lateralis (LG) muscles when compared to control athletes prior to or after impact during landing after the blocking maneuver.
METHODS: Surface electromyography (EMG) were collected from PL, TA and GL muscles of 12 athletes with functionally instable ankles (FIG - age 22.1±3.8 years) and 13 controls (CG - age 20.4±3.0 years) while performing a jump in the volley blocking. Electrodes were placed on the muscle belly, far away from the innervation zone. The task was performed 4 times. The raw EMG signal recorded during the period between take-off and 200ms after impact was full-wave rectified and a continuous integration of all the data points was performed. The integrated EMG (IEMG) and the temporal period selected were then normalized and both the final IEMG valuie and the selecion time were given the value of 1. The normalized IEMG trace was then compared to a reference line with slope equal to 1. The EMG onset latency was defined at the point in time when the distance between the normalized IEMG slope and the reference line was the gratest, and defined as a percentage of the movement cycle (from take-off to 200ms after impact). First we determined if the muscles onset ocurred before or after impact. These values were compared for each muscle between groups using Chi-square test. Then each muscle onset was analysed using ANOVA. When statiscally significance effects were found ($p<0.05$) the Scheffé *post-hoc* test was used to determine the significance in the differences between the values found for each group. Groups were also compared for each muscle using t test for independent samples when normal distribution was present, and Mann-Whitney tests when the data was not normal. We adopted $p< 0.05$.
RESULTS: Subjects in CG showed an activation prior to landing for PL ($p=0.0265$) and GL ($p=0,0182$) when compared with FIG, showing that FIG subjects present an activation pattern that can predispose to an inversion sprain since the PL is a potentially critical muscle in preventing ankle sprains injuries as a protective mechanism to balance inversion at the moment of impact. The muscle onset values for TA, PL and GL were similar between groups. CG showed differences for onset values ($p=0.0004$) within the group. GL showed an earlier activation (59.98%), PL (62.44%) activated slightly after GL, followed by the TA (73.61%). This activation pattern was similar to another studies for normal subjects. FIG didin't show differences between muscles for onset values (TA-72.37%, PL-67,19%, GL 67.54%, $p=0,0711$). This patttern also can explain the existence of instability complaints in FIG. The prior activation of PL to TA is important to prevent an inversion ankle sprain since the PL everts the ankle and acts as an antagonist to TA.
CONCLUSIONS: Our results showed that individuals with FI have a muscle activity pattern that predisposes to an ankle inversion sprain since FI subjects showed different timing pattern of activation to PL muscle when compared to control subjects, an important muscle in prevention of ankle sprains injuries.

This work was supported by FAPESP - n° 04/14116-1.

T17.P08
ELECTROMYOGRAPHIC ACTIVITY OF ANKLE MUSCULATURE IN VOLLEYBALL PLAYERS WITH FUNCTIONAL INSTABILITY DURING LANDING AFTER BLOCKING

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AIMS: The purpose of this study was to compare the muscle activation patterns of selected ankle muscles of volleyball athletes with and without functional ankle instability (FI) performing a landing after the blocking maneuver. We believe that subjects with functional ankle instability present different patterns of muscular activation when compared with normal ones.
METHODS: Surface electromyography (EMG) were collected from peroneus longus (PL), tibialis anterior (TA) and gastrocnemius lateralis (LG) muscles of 12 athletes with functionally instable ankles (FIG - age 22,1±3,8 years) and 13 controls (CG - age 20,4±3,0 years) while performing a jump in the volley blocking. Electrodes were placed on the muscle belly, far away from the innervation zone. The task was performed 4 times and the EMG signal from the instant of foot impact to 200 ms after impact (landing phase), determined by the vertical ground reaction force, was analised. Ground reaction force and EMG data were sampled at 1000 Hz. The RMS values normalized by each subject's maximal voluntary isometric contraction (MVIC) were obtained for each muscle. Coactivation index (CI) was calculated as $=2*\frac{\min[A,B]}{A+B}$, where min is the lower signal, and A and B correspond to the full-wave rectified, low-pass filtered (Butterworth - 5Hz), normalized by MVIC and integrated signal for the landing phase. The index was calculated for: 1) TA and FL (min); 2) TA and GL (min). Groups were compared using t test for independent samples when normal distribution was present, and Mann-Whitney tests when the data was not normal. We adopted $p<0.05$.
RESULTS: Results are displayed in Table 1: RMS values (% of MVIC) for TA, PL and LG muscles and coactivation index (%) for TA-FL and TA-GL for both groups.

Muscle	CG	FIG	p	CI	CG	FIG	p
TA	69,3±34,8	87,7±36,6	0,222	TA-PL	67,3±10,3	65,4±9,3	0,644
PL	51,2±25,3	59,7±24,7	0,415	TA-GL	58,0±12,6	68,7±13,2	0,060
GL	40,7±23,9	78,6±44,9	0,019*				

The RMS values showed significant differences in GL muscle activation between groups but not in the TA or PL muscles. The PL is a potentially critical muscle in preventing ankle sprains injuries as a protective mechanism to balance inversion, but interestingly we observed a significant difference only in the GL muscle: a higher activation in FIG subjects. The CI also showed for FIG subjects a tendency to a higher GL activity related to TA activity, its antagonist. These activation patterns can predispose the FI individuals to an inversion sprain since a more plantar flexion position during landing can predispose the individual to an inversion sprain.
CONCLUSIONS: Our results showed that individuals with FI have a muscle activity pattern that predisposes to an ankle inversion sprain since FI subjects in FIG showed a higher GL activation during landing when compared to controls.

This work was supported by FAPESP - n° 04/14116-1.

T17.P09
IN FIELD ACQUISITION OF SLALOM BINDING LOADS IN SNOWBOARDING

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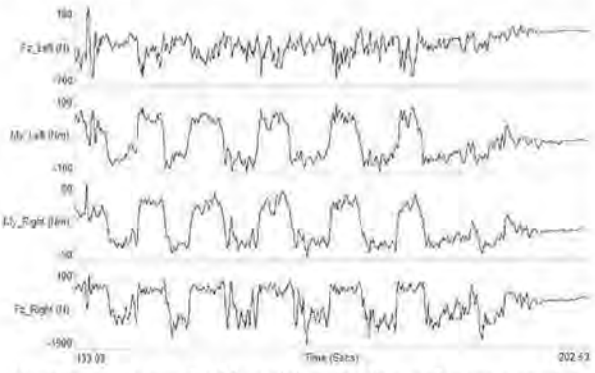
AIMS: Aim of the work was the acquisition and analysis of loads recorded in the field by means of dynamometric bindings applied to snowboards. Binding loads were collected in slalom courses on two expert amateur testers: both a soft boot and a hard boot session were recorded. Load data related to the slalom dynamics are presented and analysed both in the bindings and board reference systems.
METHODS: Two dynamometric platforms previously designed and calibrated (Bianchi, Petrone, Marchiori 2004) were used for field testing in soft and hard boot snowboards. Tests were performed using a portable data acquisition system. Two expert amateur testers were involved in the tests, adopting a regular board setup. The two tester were asked to perform a slalom between poles placed at regular longitudinal distance and span. Signal collected from the dynamometric bindings were zeroed and transformed into generalized load components by means of the available calibration matrices, referred to each binding reference system.
RESULTS: From the analysis of tester S1 as in Figure, the left and right moments My in the binding reference systems show a clear in-phase behaviour, due to the symmetrical placement of feet with respect to the board transverse axis Y_B: back curves correspond to negative My values on the bindings, front curves give slightly lower values: given the long distance between poles, the signals appear roughly squared and indicated the Heel/Toe technique of the tester. Forces normal to the boot soles Fz show different trends from Left to Right, with Left (Front) foot consistently ranging around a mean value and Right (Rear) foot that varies in phase with My signals, with higher peaks in the back curves.
The loads were resolved into the board reference frame: in this system, the roll moment BMX clearly reveals the curve direction, the pitch moment BMY shows the anterior-posterior placement of resultant forces with respect to the mid-stance, yaw moment BMZ and forward force BFX are negligible as expected, BFY is symmetrically ranging around zero dependently to the board roll angle and the force BFZ normal to the board shows highest peaks in the back curves. The synchronous acquisition of the board orientation and acceleration will complete the dynamic modelling of the tester.
CONCLUSIONS: The analysis of binding loads allowed to quantify the loads developed by the testers on a soft and hard boot snowboard during slalom: this resulted correlated with the boarding technique and will help trainers to evaluate the athletes technique.



Heel/Toe technique for S1 in slalom, bindings reference systems.

T17.P10
WILL THE OVERGROUND CONDITION AFFECT THE IMPACT SHOCK AND LOWER EXTREMITY MUSCLE ACTIVITY?

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AIMS: An overground surface condition during running is one of the factors on lower extremity overuse running injuries such as tibial stress fractures, planter fascitis, etc. It is probably that the overground condition has been associated with overuse running injuries. However, it is not clear whether the different overground condition such as asphalt or grass affect the impact shock at heel strikes and muscle activity of lower extremity during running. The purpose of this study was to investigate whether the different overground conditions affected the impact shock and muscle activity of lower extremity during running.
METHODS: Six healthy, male long-distance runners participated in this study. All subjects gave informed consent. No subjects had any disorders and injuries in lower extremity. The subjects had two trials that one was grass condision running (grass running) and the other was asphalt condition running (asphalt running) and ran at 5.0 ms^{-1} across two different overground surfaces. During running, a piezoelectric accelerometer was used to measure the peak impact shock (G) of the distal anteromedial aspect at the right tibia. And EMG activity of four leg muscles (Tibialis anterior, Gastrocnemius, Rectus femoris, and Biceps femoris) were recorded at the right leg. EMG activities were calcurated to the integration in stance phase, and standarized by maximum voluntary contraction for each muscles(%MVC). The ratio of muscle activity to peak impact shock was calcurated (%MVC/G). The data of the peak impact shock and the ratio of muscle activity to peak impact shock were analized.
Paired t-tests were used to compare each parameters (peak impact shock, the ratio of muscle activity to peak impact shock) between conditions (asphalt condition vs grass condition).
RESULTS: The peak impact shock during asphalt running (11.3 G) was significantly higher than during grass running (8.1 G) ($p<0.05$). There was significant increased in the ratio of muscle activities to peak impact shock at Gastrocnemius and Biceps femoris muscles during grass running ($p<0.05$). However, there was no significant differences in the ratio of muscle activities to peak impact shock at Tibialis anterior and Rectus femoris muscels during running between different surface conditions.
CONCLUSIONS: We concluded that grass running was at lower risk of developing overuse running injuries, and more likely to contribute to strengthening at lower extremity muscles than asphalt running.

T17.P11
EFFECT OF ALTERNATING CURRENT FREQUENCY ON ELECTRICALLY-STIMULATED QUADRICEPS FEMORIS KNEE EXTENSION TORQUE AND CURRENT AMPLITUDE

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AIMS: Determine the difference between sinusoidal alternating current (AC) carrier frequencies of 2,500 Hz and 5,000 Hz on electrically-stimulated isometric knee extension torque output of the quadriceps femoris. Determine the difference between these AC frequencies on the amount of current amplitude necessary to produce isometric knee extension torque output of the quadriceps femoris.
METHODS: There were 10 healthy uninjured volunteers, eight male and two female, mean age 32 years (range 24-37 years).

Mean isometric knee extension torque was measured using an isokinetic dynamometer, set at a speed of 0 degrees/second. Subjects were seated at the dynamometer with the knee positioned at 60 degrees of flexion and the backrest at a 70-degree angle to the seat pan. After the maximum voluntary isometric contraction (MVIC) torque was determined, each subject underwent electrical stimulation (ES) of their quadriceps femoris muscles. The maximum tolerated contraction (MTC) torque produced by ES of the Quadriceps femoris was determined for each of the AC carrier frequencies. The order of ES MTC testing was randomized to limit test order bias. The torque output and current amplitude were recorded for each ES MTC. Mean %MVIC [(MTC/MVIC) 100] was calculated for each AC carrier frequency for each subject, and was used as the criterion value for the torque comparisons. Data were analyzed using two-tailed paired t-tests. The alpha level was 0.05.

RESULTS: The mean %MVIC for 2,500 Hz was 37.6% and for 5,000 Hz it was 37.2%. These values were not significantly different ($p=0.944$). However, the current amplitude required to produce the torque for 2,500 Hz was 91.9 mA and for 5,000 Hz it was 167.4 mA ($p<0.001$).

CONCLUSIONS: The 5,000-Hz AC required nearly twice the amount of current amplitude as did the 2,500-Hz AC to produce an equivalent amount of knee extension torque. This is most likely because the cycle duration at 2,500 Hz is 500 microseconds, which is twice that at 5,000 Hz. Both current amplitude and cycle duration contribute to charge, which is largely responsible for the magnitude of the physiologic effect (i.e., muscle contraction). Therefore, it appears that the lower medium frequency AC is more efficient for generating quadriceps femoris knee extension torque.

T17.P12
MICROGRAVITY INDUCED CHANGES TO THE SEMG/FORCE RELATIONSHIP

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AIMS: The overall objective of this work is to understand the neuromuscular basis for microgravity-induced degradation in motor function associated with manned space flight. This understanding is essential for the educated design of exercise programs to counter the effects of microgravity, as well as to validate ground-based models. The neural control of muscular force was studied by comparing the relative contribution of muscles around the knee joint.

METHODS: Astronauts are being tested pre-flight and post-flight for short duration Space Shuttle missions. Surface electromyographic (sEMG) signals are recorded concurrently from three knee extensor muscles (Vastus Medialis (VM), Vastus Lateralis (VL), Rectus Femoris (RF)) and one knee flexor muscle (Biceps Femoris (BF)). The sEMG signals are acquired while subjects trace trapezoidal force trajectories on a computer screen by sustaining isometric knee extension force at specified percentages of their maximum voluntary contraction (20%, 50%, 80%, and 100% MVC). The sEMG data are processed for the plateau portion of the force trajectory where the ratio of the Root Mean Square (RMS) of the signal to the contractile force is calculated. This ratio is analyzed to determine whether neural excitation to these muscles, normalized with respect to force, is modified following exposure to microgravity.

RESULTS: To date, we have successfully collected sEMG and Force data in 1 astronaut subject for three days of baseline testing prior to launch [Launch -120, -119, and -116 days] and four days of testing following a 14-day Space Shuttle mission [Landing Day +0, +1, +3, +7, +13 days]. Figure 1 shows changes in the RMS_{EMG}/Force ratios for the RF muscle on different test days. The other thigh muscles showed a similar pattern of behavior, where the greatest increase in the ratio was observed on landing day (R+0) followed by a gradual return to baseline by the 13th post-flight day (R+13) for most contractions.

CONCLUSIONS: The magnitude of the changes in the RMS_{EMG}/Force ratio for each of the %MVC contractions was greater than the day-to-day variability observed over the respective baseline period or the the within-day repeated trials. This finding suggests that these changes were likely attributed to exposure to the Space flight conditions. We are currently analyzing the data to test the possibility that the changes were due to increased co-contraction at the knee.

This project was funded by NASA Grant No. 99E192.

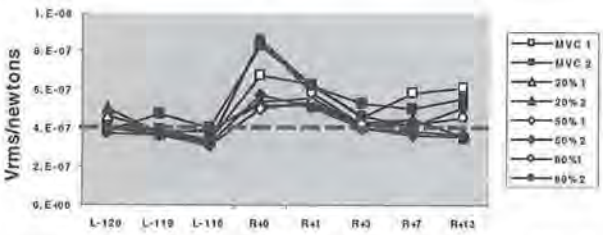

Figure 1. RMS_{EMG}/Force ratio for two repeated contractions each at 100%, 80%, 50%, and 20% of maximum force (MVC) from the Rectus Femoris muscle of an astronaut shown for 3 pre-flight (L- days) and 4 post-flight (R+ days) following a 14-day Space Shuttle mission.

Technology transfer

T18.P01
ELECTRO-MECHANICAL STABILITY OF SURFACE EMG SENSORS

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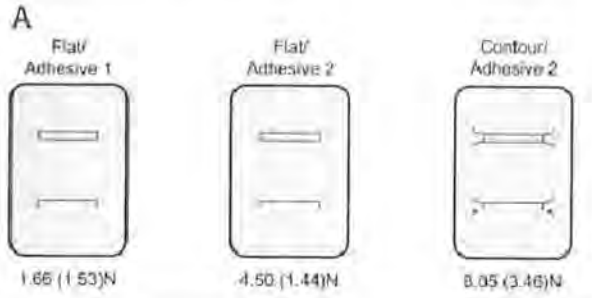
AIMS: The purpose of this study was to test the electro-mechanical performance of different active surface electromyographic (sEMG) sensors. The study focuses on two aspects of sensor design that are associated with electro-mechanical stability: A) surface contour and adhesive liner of the sensor, and B) the use of conductive interfaces (skin preps and gels) between the sensor and the skin. The long term goals are to advance sEMG sensor design and guidelines for their use to improve signal recordings during vigorous activities.
METHODS: Twenty-four subjects (24.1±3.9 y.o) participated in Part A of the study which compared the adhesive properties of sEMG sensors with different surface contours and adhesive liners (Fig. A) under "normal" and "perspiration" skin conditions. Adhesion was measured at baseline and following 14-min of exercise on a stationary bicycle. A custom mechanical "Peel Test" device was used to measure the amount of force needed to peel the sensor from the skin. A sub-set of these subjects (n=5; 23.1±3.3 y.o) participated in Part B of the study, which compared motion artifact amplitude among 4 identical sEMG sensors with different skin/sensor interfaces (Fig. B). Motion artifact was assessed for shear and normal forces applied using a custom device which imparted either sinusoidal or impact force perturbations. The artifacts were measures before and after the same exercise protocol as in Study A.
RESULTS: STUDY A: Substituting the adhesive in the benchmark sensor (Flat-Adhesive1) with a more aggresive adhesive, 2.0 vs. 3.7lb/in., resulted in significant increases in mean Peel force as indicated in Fig. A. Furthermore, contouring the detection surface of the sensor resulted in significant additional increases in mean Peel force. Peel force significantly decreased for all sensors following 14 minutes of exercise.
STUDY B: The addition of a conductive adhesive hydro gel to the detection bars (Small Gel sensor and Large Gel sensor in Fig. B) significantly increased motion artifacts, particularly for shear impact tests that followed the exercise protocol. The addition of a surfactant to the detection bars (Liquinox® sensor) had no significant effect on motion artifact when compared to the Dry sensor. Both of these sensors had the least amount of motion artifact, overall.
CONCLUSIONS: Changes to the adhesive liner and surface contouring can provide significant improvement in sensor adhesion. Application of hydro gel to sensor contacts should be used with caution to avoid motion artifacts resulting from mechanical perturbations, especially when the skin is moistened by accumulated perspiration.

This project was funded in part by NIH/SBIR GRANT AWARD NO. 1R43 HD35412.



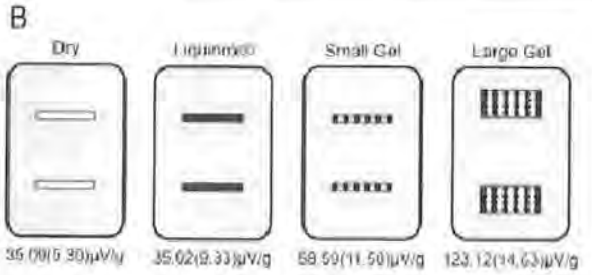


Fig A. Three sensors and their baseline Mean (SD) peel-force values (Newtons) as tested in Part A.
Fig B. Four sensor interface conditions and their Mean (SD) Artifact/ Acceleration (microvolts/g) for Shear Impact Forces post exercise as tested in Part B.

Virtual and Augmented Reality in Rehabilitation

REGULATION OF BALANCE UNDER CONCORDANT AND DISCORDANT SOMATOSENSORY AND VISUAL PERTURBATIONS

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AIMS: The aims of these experiments were: 1) to explore the interactions of the somatosensory and visual systems on the control of equilibrium during stance and 2) to determine how aging affects the capability of the center nervous system in resolving sensory conflicts.
METHODS: Healty young (24-35 yrs) and older (65-75 yrs) adults were asked to maintain their balance while exposed to visual and/or surface ramp perturbations of 8° (36°/s) in each direction of pitch/roll/yaw randomly presented during quiet stance. Visual perturbations were induced by sudden movements of a virtual environment viewed through a helmet-mounted display, and combined with either no surface perturbation, surface perturbation in the same direction, or surface perturbation in the opposite direction. The EMG responses of eight bilateral postural muscles, body kinematics and ground reaction forces were captured. EMG onset latencies and integrals as well as center of pressure (CoP) were calculated and compared.
RESULTS: When the visual environments were manipulated to be discordant with the surface perturbations, older adults took more steps, had increased EMG activation and longer latencies, as well as larger CoP amplitudes, as compared to conditions where the perturbations were concordant.
In young adults, muscle recruitment generally followed a distal-to-proximal activation sequence, regardless of the presence or absence of sensory conflicts. In older adults, the sequence of EMG activation was less consistent especially under conditions of discordant perturbations. In some older subjects, following discordant visual and somatosensory perturbations, activation of neck flexors and neck extensors preceeded activation of distal leg muscles. Generaly, the EMG onset latencies of older adults, which were already delayed compared to young adults, were further prolonged by 40-60 ms in the presence of discordant perturbations. CoP excursions were sensitive to the presence of sensory conflicts and direction of perturbations. During conditions of sensory conflicts, older adults displayed significantly larger amplitudes of CoP displacements in both anteroposterior and mediolateral directions during picth and roll visual perturbations respectively. For young adults, the sensory conflicts induce significanly larger CoP amplitudes only in the anteroposterior direction.
CONCLUSIONS: Conflicting and complementary visual and somatosensory information triggered by external stimuli modulate automatic postural responses in both young and older adults. However, the presence of sensory conflicts had a significantly larger impact on the regulation of balance in older adults. Older adults relied more on vison as compared to young adults. Aging affects the interaction of the somatosensory and visual systems on the control of equilibrium during standing and the ability of CNS to resolve sensory conflicts.

VISUAL CONTEXT INFLUENCES INTERSEGMENTAL COORDINATION IN HEALTHY YOUNG AND ELDERLY ADULTS

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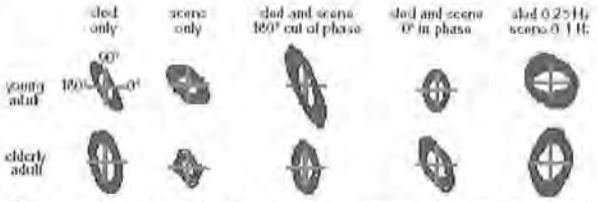
3) Middle East Technical University, Dept. of Engineering Sciences, Ankara, Turkey

AIMS: To determine how the postural system reorganizes to accommodate conflict between self-motion and motion of the visual world we have incorporated time dependence into a multivariate model [Kuo et al., Exp. Brain Res 1998;122:185-195].
METHODS: Seven healthy young (22-37 yrs) and six elderly (60-78 yrs) adults stood on a platform (sled) translating sinusoidally (±10 cm at 0.25 Hz) in the a-p direction within an immersive, wide field of view virtual environment (scene) that moved foreaft ±3 m/sec at 0.1 Hz or 0.25 Hz. Sled and scene were moved separately and together with different amplitudes but at the same frequency, or with a different amplitude and frequency. Kinematics of trunk and shank were collected with an Optotrak system. Relative angles between the trunk and shank were plotted on a 2-D plane for each 16 sec period with an 8 sec overlap across each 140 sec trial. Variability between the segments was calculated. The eigenvalues and related eigenvectors of the covariance matrix were used to draw major and minor axes of an ellipse. When both segments rotated proportionally in the same direction (inverted pendulum strategy), the ellipse exhibited an orientation angle (α)<90°. When both segments rotated proportionally in opposite directions (hip strategy), α fell between 90°-180°. The relative contribution of the shank to the response decreased as the ratio of the major and minor axes of the ellipse (r) neared unity. Values of α and r were compared across visual protocols with parametric and non-parametric repeated measures ANOVA, respectively.
RESULTS: Both r and α varied significantly across visual protocols ($p<0.0001$). Young adults predominantly demonstrated hip strategy responses when the sled or scene moved alone or when motion of the scene was directionally appropriate for selfmotion (see Figure). When the scene was inappropriate in direction (0° in phase) or frequency (scene at 0.1 Hz), inverted pendulum responses appeared and r was significantly larger than with either sled or scene motion only ($p<0.01$). Elderly subjects exhibited hip strategy responses having a significantly large response at the shank only when the scene was 0° in phase. For the other conditions their responses occurred predominantly on the axis between the two stategies.
CONCLUSIONS: Young adults modified both the temporal and spatial components of intersegmental coordination with changes in visual conditions, exhibiting a more unstable strategy when visual scene motion did not match their self-motion. Elderly subjects primarily modulated segmental magnitudes along the vertical axis suggesting that they increased motion as a less stable inverted pendulum rather than switching to a more stable hip strategy. Variations in intersegmental coordination across visual conditions demonstrate that the specific visual context is an important component of the motor plan calculations for the organization of the postural response.



A sequence of 16 overlaid ellipses from one trial of each protocol

This work was supported by NIH-NIDCD grants DC01125 and DC05235.

STIMULATION THROUGH SIMULATION: MENTAL PRACTICE WITH VIRTUAL REALITY FOR POST-STROKE REHABILITATION

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AIMS: In the field of sport psychology, it has long been known that mental practice (MP) with motor imagery (MI) can optimise the execution of movements in athletes, and help novices in learning motor skills. In recent years, several clinical studies have tested MP with MI as a restorative technique for post-stroke hemiparesis, with encouraging results. To account for these findings, it has been suggested that mental training repetitively activates cerebral and cerebellar sensorimotor structures damaged by a stroke, thereby engaging compensatory networks to promote motor rehabilitation. This hypothesis is supported by converging evidence from neuroimagery studies, showing similar neural networks associated with imagination and execution of a movement. However, the use of mental training in rehabilitation of brain-injured patients poses practical issues. Though there is evidence that brain-injured, hemiplegic patients can retain the ability to mentally simulate movements they can no longer perform, this task is cognitively demanding. the aim of the present project was to use movement-tracking and visualization technology to guide mental practice in the rehabilitation of upper-limb hemiparesis following stroke.
METHODS: The system consists of a retro-projected horizontal screen (a piece of metacrilate 1200x800 mm in size) incorporated in a wooden table; a 1500 lumens LCD projector with parallax correction; a mirror that reflects the projector beam onto the horizontal screen; two movement tracker sensors (Polhemus Isotrack II) positioned on the hand and on the forearm of the patient; a pc equipped with graphic accellerator. First, the therapist shows the patient how to perform the movement with the unaffected arm. When the patient performs the task, the system registers the movement and generates its mirrored three-dimensional simulation. Then, the virtual arm is superimposed over the (unseen) paretic limb, so that the patient can observe and see as if the impaired arm is actually performing the movement. Next, the patient is asked to mentally rehearse the movement he has just observed, taking a first-person perspective. Last, the patient has to perform the movement with the affected arm. During the execution of the physical exercise with paretic arm, the system tracks the movement, and measures its deviation from the movement performed with the nonparetic arm. Using this measurement, which is done in real time, the system provides the patient with audiovisual feedback describing his performance on the task. At the end of the laboratory training phase, patients use a portable display device to practice at home.
RESULTS: Pilot clinical trials are in progress; preliminary results show that the observation of the simulated movement registered from the healthy arm helps the patient in creating a compelling representation of the movement to be mentally rehearsed.
CONCLUSIONS: The proposed approach is based on the hypotheses that: (a) MP with MI can be facilitated using a technology medium; (b) the inclusion of an home-rehabilitation phase allows the patient to practice more often than would otherwise be possible, therefore increasing effectiveness of training; (c) the use of visualization technology is likely to reduce the need for skilled support, therefore improving the cost-effectiveness of training. A future goal is to systematically define which features of the procedure are most useful, as well as to identify the best way to introduce technology-supported mental training into current practice.

The virtual reality mirror prototype in action

INVESTIGATING ADVANCED MYOELECTRIC CONTROL FOR MULTIFUNCTION UPPER-EXTERMITY PROSTHESES USING VIRTUAL REALITY

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AIMS: Advancements in myoelectric signal (MES) control for upper-extremity prostheses have led to highly accurate, multifunction control schemes [1]. However, availability of multiple degree of freedom prostheses is limited and hindered by slower development and high cost. The objective of this work was to develop a virtual environment wherein interactive assessments of these multifunction MES control schemes could occur without the need for a physical multifunction device. A secondary objective was use of the virtual system in a clinical assessment to relate virtual limb usability to MES classification accuracy. This investigation was motivated by the fact that real-time use of multifunction MES pattern recognition controllers for multifunction devices has had limited quantitative assessment.
METHODS: A fully integrated graphical user interface (GUI) was created to host a real-time, multifunction, virtual, upper-extremity limb with a clothes pin task [2] for clinical assessment. The 3D graphical representation of a human arm is able to perform all physiologically accurate motions from shoulder to wrist and includes two hand grips: a chuck (power) grip and a key grip. The virtual limb is controlled in real-time as amplified MES signals are fed to the host PC via A/D hardware and classified using one of many available multifunction control schemes. Normally limbed subjects participated in sessions where surface MES data were recorded for six classes of motion. Thirty-six continuous multifunction MES control schemes were processed with results presented as percent classification accuracies. Subjects then performed a functional test with the virtual limb (moving virtual "clothes pins" from a horizontal bar to a vertical bar) using the 'best', 'worst' and 'moderate' control schemes.

Subject performing the virtual clothes pin functional task

Subjects repeated the process for five discrete sessions to provide insight into improved performance and repeatability of 'best' control algorithms.

RESULTS: Subjects involved in the study were all able to control the virtual limb and complete the clothes pin tasks. No subjects described or exhibited confusion in interaction with the virtual environment. Timed results from the virtual clothes pin placements were compared with the classification accuracies of the MES controller used. These results suggested lower than expected correlation between classification accuracy and usability.

CONCLUSIONS: The developed virtual limb environment and associated virtual functional task have been useful for assessment and refinement of multifunction MES control systems. This preliminary work suggests the need for further functional testing in virtual space to test both clinical prosthetic function and advancements in control.

[1] K. Englehart, and B. Hudgins, "A robust, real-time control scheme for multifunction myoelectric control," IEEE Trans. Biomed. Eng., vol. 50, pp. 848-854, Jul. 2003.

[2] T.A. Kuiken, G.A. Dumanian, R.D. Lipschutz, L.A. Miller, and K.A. Stubblefield, "Targeted muscle reinnervation for improved myoelectric prosthesis control," in Proc. of the 2nd Intl. IEEE EMBS Conf. on Neural Eng., Arlington, VA, March 2005, pp. 396-399.

T19.P01
EFFECTS ON BALANCE AND STRENGTH FOLLOWING RESISTANCE EXERCISE PERFORMED ON AN UNSTABLE SURFACE IN A NINETY DEGREE TILTED ENVIRONMENT

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AIMS: This study is part of an ongoing project that evaluates various forms of strength and balance exercise performed in a 90 degree tilted environment where, similar to conditions in microgravity, the vestibular tilt orientation mechanism for upright balance control is ineffective. The current aim is to study effects of combined resistance and balance exercise on parameters of balance and strength. A better understanding of changes in neuromuscular function related to the proposed exercises will provide a basis for designing more effective training programs for astronauts, the elderly and athletes.
METHODS: A group of 12 healthy young subjects (6 male of age 19.7±0.5 y, height 176.8±12.2 cm, weight 72.7±6.8 kg, and 6 female of age 20.0±1.4 y, height 164.6±6.1 cm, weight 62.9±9.9 kg) performed a leg extension exercise (6 sets of 10 reps, separated by 1 min of rest) for a period of 4-weeks (4 sessions/week), on a balancing board while in a supine position. Subject wore a backpack frame that was floating on air-bearings allowing movements for balance control to be performed in the frontal plane. Subjects' visual surround was consistent with being upright in an upright environment. Progression was achieved by increasing load (from 50% to 70-75% of 1RM) and decreasing stability (two-legs and one-leg balancing on different balance boards). Pre- and post-testing of balance function was performed under both static and dynamic conditions (standing on two-legs and one-leg, with eyes open and eyes closed, respectively) using a force plate mounted in a moving balance platform. Ground reaction forces were recorded at 100 Hz and code written in MatLab was used to extract traditional sway measures and stabilogram-diffusion parameters from each data set. The level of self-perceived balance was assessed using a Berg Scale. An Ariel Dynamics Computerized Exercise System was used to measure strength during squats at isokinetic velocities of 10 deg/s and 35 deg/s.
RESULTS: Initial analysis indicates an increase in strength at the slower but not at the higher isokinetic velocity (10 deg/s and 35 deg/s, respectively). Furthermore, subjective perception of balance during post-testing suggests improved performance during one- as well as two-legged standing.
CONCLUSIONS: If the final results support the hypothesis that resistance exercise performed on a balancing board in a tilted room can improve both strength and upright balance function it could have important implications for in-flight training regimens for astronauts as well as rehabilitation of different categories of patients on earth including athletes.

This work was supported through a NASA Cooperative Agreement NCC 9-58 with the National Space Biomedical Research Institute (Dr. Oddsson). Dr. Zemkova's effort was supported by a Fulbright grant.

T19.P02
EFFECT OF VISUAL MOTION ON BALANCE DURING A DUAL TASK PERFORMED WITHIN A DYNAMIC ENVIRONMENT

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AIMS: Previous studies indicated that an increased dependence on visual information in labyrinthine deficient (LD) patients could produce instability. Focusing on a stationary stimulus within the environment, however, has been shown to assist in postural stabilization. We explored the effect of background visual field motion on postural stability while subjects reached toward a stationary target situated in the central visual field.
METHODS: Three healthy young subjects and one bilateral LD adult (72 yo) stood on a platform in the dark or within an immersive 3D wide field of view virtual environment (scene). Subjects were exposed to natural visual feedback or roll motion of the scene while the platform was either still or referenced to the subject's sway. Subjects were instructed either to stand quietly or to point, at their own pace, toward two stationary virtual targets that were located at shoulder level. Whole body centre of mass (COM) and center of pressure (COP) were calculated. Variability in postural stability was determined for each trial using principal components analysis where 95% tolerance ellipses (reflecting the variable errors around the mean) were constructed from the calculated COM and COP. The area of each ellipse was then characterized by the computed eigenvalues.
RESULTS: Side-to-side and anterior-posterior shifts in COM and COP increased with sway referencing. With roll visual motion, COM and COP clearly shifted in the direction of visual motion for all subjects on both a stable or sway referenced platform. When pointing toward the targets, however, instability increased for the healthy subjects (i.e., higher values of the ellipse area) but decreased for the LD patient. Area of the tolerance ellipses was 10 times larger for the LD patient compared to the young subjects in all conditions. The patient also frequently relied on the safety harness to stabilize herself when optic flow motion (primarily in roll) was present, which further enlarged the ellipse area.
CONCLUSIONS: Both the background optic flow motion and the presence of a stationary target in the central field had an influence on postural sway. In healthy subjects, sway increased with roll motion compared to a natural scene and increased further when the target task was added. Surprisingly the LD patient showed more stability while hitting the target when exposed to roll motion than with a rotating visual field alone. This would suggest that the LD patient was able to suppress the effect from background motion of the visual field.

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Applications in Ergonomics

FORCE AND ELECTROMYOGRAPHY DURING SQUAT AND STOOP LIFTING, PUSH AND PULL

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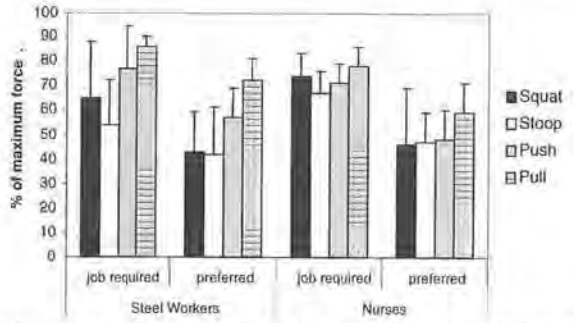
AIMS: The objectives of this study were to evaluate the maximum, job required, and preferred level of force and electromyographic activity (EMG) of nurses and steel workers during squat and stoop lifting, pushing and pulling.
METHODS: Ten male steel workers and ten female nurses participated in the study. The force and EMG of the erector spinae (bilateral electrodes placed 3 cm of the midline at L2/L3 level) and rectus abdominis (bilateral electrodes placed 3 cm from midline and 3 cm above umbilicus) were recorded. Three five-second trials during squat and stoop lifting, pushing and pulling were done: maximum voluntary force (MVF), job required, and preferred working level to "never go home sore and never get injured" (12 tests in total per subject).
RESULTS: The steel workers and nurses' MVF were respectively 579±128 N and 314±88 N for squat lifting ($p<0.002$); 559±186 N and 314±88 kg for stoop lifting ($p<0.002$); 255±88 N and 216±78 N for pushing ($p>0.05$), and 157±49 kg and 186±78 N for pulling ($p>0.05$). The MVF during lifting was higher than during push and pull for both groups ($p<0.02$). For the steel workers, the erector spinae EMG during lifting was higher than during push and pull ($p<0.046$). Push tended to be higher than pull; this was significant for the left erector spinae EMG ($p=0.007$). The opposite relation was found for the rectus abdominis EGM, which tended to be higher during pull; this was significant in relation to push ($p<0.024$). For the nurses, the EMG of both muscles was higher during squat lifting ($p<0.02$). This finding may be explained by an increased handle distance during squat lifting because it did not fit between the knees. The Figure presents the required and preferred force level (% of MVF) during squat and stoop lifting, pushing and pulling. The job required exertion tended to be higher than the preferred level for both groups. Only for stoop lifting by the steel workers the difference between job required and preferred force level was not statistically significant. This may be explained by the fact that these workers tend not to perform this type of lifting during the job. Only the preferred pull level was higher for the steel workers than for the nurses ($p=0.015$). Only for pull the difference between the right erector spinae EMG during the job required exertion and during the preferred level was not statistically significant. For the left erector spinae, this difference was only significant for squat lifting. This shows that even in symmetrical tasks there are differences between the left and right erector spinae muscles. No significant differences were found for the rectus abdominis EMG.
CONCLUSIONS: There are workload differences between the jobs and gender differences in physical capacity. This methodology is useful to identify problems/risks in jobs with high incidence of musculoskeletal disorders. Job modifications and training programs can be designed and assessed based on these results. Further studies could evaluate if interventions designed based on the information gathered using this methodology can successfully reduce the incidence of work-related musculoskeletal disorders.



Job required and preferred force level as a percentage of MVF of the steel workers and nurses

OBESITY AFFECTS TRUNK POSTURE AND LOAD DURING A STANDING WORK TASK

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AIMS: Mechanical obstruction by excess abdominal adipose tissue may lead to an altered posture when using a work station. Musculoskeletal load on the trunk muscles hence may be increased as a consequence of altered posture, increased load or both. The aim of the project was to investigate hip joint moments, hip-to-bench distance and posture of the thoracic and pelvic segments, hip joint and the thoracolumbar spine during a standing work task in obese subjects.
METHODS: Ten obese subjects (44.5±10.3 years, height 164.3±5.7 cm, mass 104.7±16.1 kg, waist girth 121.2±16.8 cm, BMI 38.9±6.6 kgm^{-2}) and ten age and height matched normal weight female subjects (44.2±10.1 years, height 164.2±4.7 cm, mass 58.4±3.6 kg, waist girth 79.6±6.4 cm, BMI 21.7±1.5 kgm^{-2}) performed three trials of a standing work task at a 90 cm bench, 18 cm in from the bench edge. Markers were placed on T4, T10, L5 and S3, the bench edge, right greater trochanter, humeral epicondyle and ulnar head. All 2D data (50 Hz) were collected, digitized and optimally filtered (Jackson Knee method with quintic spline processor) using Peak Motus (Ver 7). Segment lengths were noted for trunk, upper arm and forearm and hand with Winter (1990) used for anthropometric ratios. Hip joint moment was divided by body weight and height. Differences between groups were investigated using Kruskal-Wallis tests and Spearman's Rank Order Correlations investigated relationships with BMI.
RESULTS: The obese group showed a significantly more flexed posture for the thoracic and pelvic segments, and the hip joint and thoracolumbar spines, and the hip joint net moment was significantly larger in comparison to the normal weight subjects (Table). During the initial quiet standing posture, the obese group stood further back from the bench with the hip-to-bench distance significantly larger than that for the normal weight subjects. BMI showed a high positive correlation with the posture of the thoracic segment ($rho=0.77$, $p<0.001$), hip joint moment ($rho=0.83$, $p<0.001$), and hip-to-bench distance ($rho=0.74$, $p<0.001$). BMI also showed a moderate positive correlation with the posture of the pelvic segment ($rho=0.53$, $p<0.001$), hip joint ($rho=0.57$, $p<0.001$), and thoracolumbar spine ($rho=0.63$, $p<0.001$). Thus indicating as BMI increased the posture was more flexed, hip joint moment increased, and the hip-to-bench distance was increased.
CONCLUSIONS: The standing work task showed an increase in hip joint moment not accounted for by increased mass. Obese subjects, however, stood further away from the bench and as a consequence had a more flexed posture. Therefore the increased moment was likely to have been the result of postural changes rather than increased body mass.
These postural adaptations increased with increasing BMI. Measures to prevent the increased trunk load in obesity should be directed at both preventing adverse postural changes and minimizing the effect load due to altered body weight and distribution. Further research is required to develop design strategies to minimize postural adaptations consequent to increased body dimensions as seen in obesity.

	Obese	Normal	P
Pelvis	2.2(1.7)	0.3(1.4)	0.010*
Thorax	5.6(4.5)	0.8(1.4)	0.002*
Thoracolumbar	3.4(3.3)	0.5(1.4)	0.028*
Hip joint	1.2(1.5)	-0.3(1.1)	0.023*
Hip-to-bench	23.0(2.9)	17.0(3.2)	0.001*
Hip joint Moment	23.3(10.6)	7.6(6.1)	0.001*

* significant at $p \leq 0.05$

Trunk posture (°), hip-to-bench (cm) and moment ($x10^{-3}$ Nm BW^{-1} H^{-1})

EVALUATION OF VEHICLE DRIVEABILITY BY USING DRIVER'S SURFACE EMG

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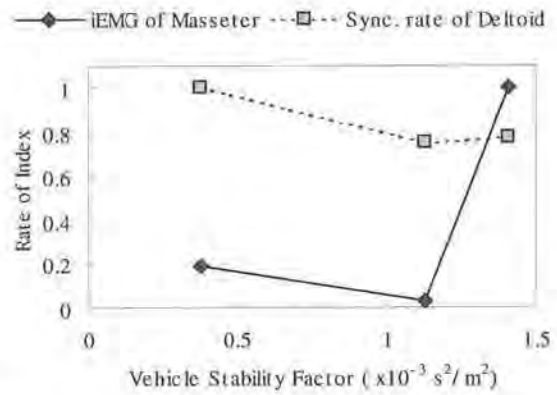
AIMS: To detect driver's stresses while driving vehicles, we focus the relationship between driver's muscular activities and driving tasks. Certainly, various EMG applications have been reported in ergonomics. As for application to drivability, however, there have been few examples. While there were many reports which examine the ECG, EOG of drivers. Given this background, this paper discusses about an approach to the evaluating method of drivability by using EMG.
METHODS: In a closed proving ground, the examination was carried out to examine the relations between drive's muscular activities and driving tasks, with different 3 characteristics of vehicle dynamics. To make the different 3 characteristics, 3 different tires were installed on the same test vehicle. Driver's muscular activities of upper limbs (deltoid, biceps, triceps), neck (sternocleido-mastoid) and mandible (masetter) were measured by using surface EMG. In addition, driver's ECG, driving operations (steering angle and force) and vehicle dynamics were measured.
RESULTS: On the slalom test, the activity of the one side of deltoid anterior grows concerning with steering operation, the activity of the other side becomes smaller, so that alternation was found on the both side of deltoid anterior. This can be explained by the symmetry of human body and steering operation. The result shows that vehicle characteristics affected the alternation of left and right deltoid anterior; frequency of this synchronous activity increased on the vehicle with lower stability. On the other hand, the activity of masseter was obviously non-related to driving operations. This activity increased on the vehicle with lower stability and too much stability.
CONCLUSIONS: Muscular activities of driver can be separated into two categories. One is the activities involved with driving operations. They are mainly applied to an evaluation of maneuverability and physical workload of driver, which is an analysis of intensity or pattern of EMG accompanying with driving operation. The other is the activities independent of driving operations. They are mainly applied to an evaluation of mental workload of drivers, which is an analysis of intensity or pattern of EMG independent of driving operation such as chewing or tense of drivers. EMG from drivers can be a good source for drivability analysis.



Relationsip between vehicle stability and index from driver's muscular activity. Synchronous rate of deltoid was caliculate from liner enveloped emg of left and right deltoid anterior

SURFACE ELECTROMYOGRAPHY RECORDINGS OF CAR DRIVERS AND PASSENGERS SUBJECTED TO LATERAL ACCELERATIONS

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AIMS: A previous study demonstrated that recordings from passengers were able to objectively assess vehicle comfort during lateral accelerations. However, given that the responses of drivers may be of greater importance than those of passengers, it is important to evaluate driver comfort. Therefore, the aim of this paper was to evaluate lateral support of cars using electromyography recordings on both drivers and passengers.
METHODS: Eighteen male subjects participated in the study. Surface EMG signals were collected bilaterally from the cervical erector spinae (CES), external oblique (EO) and vastus lateralis (VL) muscles using Red Dot 2238 surface electrodes, and from the latissimus dorsi (LD) and erector spinae (ES) muscles using Red Dot 2330 electrodes. Data acquisition was performed using a NIDAQ card 6036E with a sampling frequency of 2000 Hz, a pre-amplification of 5000 and band-pass filtering between 20 and 500 Hz. All testing was performed at the Renault Centre Technique d'Aubevoye (CTA), on a private circuit consisting of three left and three right turns. Subjects were tested as both drivers and passengers in two vehicles, A and B, with each test lasting four minutes. The RMS value of the EMG signals for each turn was retained as the dependent variable with the corresponding acceleration as the independent variable. Data were normalized with repect to their mean value for each subject and each muscle.
RESULTS: Muscle activation levels of ES and VE muscles were significantly affected by the vehicle type for passengers, with greater activation levels observed for vehicle A. No differences were observed for drivers. When each car was analysed individually, vehicle A induced significantly greater activity for passengers than for drivers, whereas vehicle B produced the opposite effect. The resulting classification for both drivers and passengers, in terms of muscle activity level, was Passenger A > (Driver A = Driver B) > Passenger B, where > indicates a significantly greater muscle activation and = indicates the lack of any statistical difference.
CONCLUSIONS: In this study, it was not possible to differentiate between vehicles using EMG signals obtained from drivers. In contrast, EMG signals from passengers varied according to the vehicle used. In addition, the relationship between EMG activation levels for drivers and passengers were reversed for the two cars. The most likely explanation is that the action of holding the steering wheel while driving the car created an aid for lateral stability for vehicle A. However, this effect was absent for vehicle B as the new generation steering wheel was very responsive, meaning that drivers were unable to use it for lateral support without modifying the trajectory of the car. In conclusion, EMG studies of lateral support in cars should be performed on passengers in order to avoid any masking effect created by the action of driving.

NEUROMUSCULAR DEMANDS ON MASSAGE THERAPIST'S PERFORMING CORPORATE MASSAGES

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AIMS: A corporate massage is a standardized 15 minute treatment applied over the client's clothing as a stress release intended to be conducted on a work break at the work site. The massage can be conducted with the client on a massage table or

in a massage chair. It is hypothesized that the client's position will have a significant impact on the upper extremity muscular demands of the therapist. The purpose of this study was to test this hypothesis.

METHODS: Eight female massage therapists (mean age=23.5±4.3 years; height=166.6±5.1 cm; weight=72.4±13.4 kg) volunteered for this study. In a randomized order, the corporate massage was performed on a client lying on a massage table and sitting in a massage chair, with a ten minute break provided between massages. A Noraxon Telemyo 2400R wireless electromyography (EMG) system was used to collect data from eight muscles of the right side. The muscles of interest were the anterior and posterior deltoid, middle and upper trapezius, flexor carpi radialis, extensor carpi radialis, lateral triceps and lumbar erector spinae. Surface electrodes (3M Red Dot) were placed over the belly of each muscle. Each distinct phase of the massage was segmented into a period of interest for processing resulting in 14 distinct periods for each of the two conditions (chair and table). The phases characterize a change in massage technique. The integrated EMG (iEMG) was used to quantify the amplitude of the signals and used for comparison. A general linear model (GLM) analysis of variance (ANOVA) was used to compare differences across subjects, conditions and periods. The significance level was set to $p<0.05$.

RESULTS: It was found that there were significant variations across subjects in terms of the EMG activity. It was also found that the EMG activity levels changed across each of the 14 periods for both the chair and table conditions. Interestingly, it was also found that there were significant differences in the muscle activity over the 14 periods between the chair and table condition for four muscles; the anterior deltoid ($p=0.000$), extensor carpi radialis ($p=0.011$), upper trapezius ($p=0.009$), and the lateral triceps ($p=0.006$). Overall there were higher EMG activity levels for these four muscles during the chair condition compared to the table condition.

CONCLUSIONS: This preliminary data shows that there are differences in muscle activity of the upper limb of massage therapists between two work positions. The indication that during the chair position there is significantly higher EMG activity suggests that further investigation be done to determine the impact on overall work health and fatigue.

A BIOFEEDBACK SYSTEM FOR PHYSICAL REEDUCATION TO AVOID MOVEMENTS CAUSING LOW BACK PAIN

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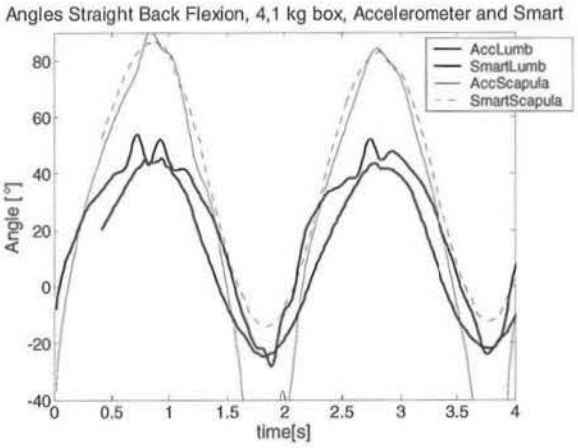
AIMS: Low back pain is often the consequence of a habitual posture leading to repetitive overloading of the spine. To design a tool for the postural re-education of people, being treated for low back pain, a wearable biofeedback system is being developed and should help the user to perform movements that complies with standards for manual handling [ISO 11228-1, "Ergonomics-Manual Handling. Part1 Lifting and carrying"].

METHODS: The system consists of a control unit, connected to accelerometers and EMG electrodes which are placed on the back of the subject. The unit sounds an alarm when the subject makes movements that potentially can cause injury to the back, such as lifting and moving heavy objects. Two accelerometers are used to measure the inclination in degrees, with respect to the gravity and thereby estimate the curvature of the lumbar part of the spine. Also the EMG signal is used as an indication for the load and imbalance of the back muscles.

RESULTS: A preliminary study indicates the importance of avoiding bending the back while lifting, and twisting the spine while moving heavy objects. Results from different correct and incorrect postures of healthy subjects will be presented. A comparison with an optoelectronic movement analysis system (SMART, BTS spa) has demonstrated that a rough estimation of the curvature and inclination of the back is possible with two accelerometers for a 2 seconds lifting movement with an error less than 6° for the lumbar accelerometer and 14° for the accelerometer on the level of inferior scapula. A rule based approach is to be implemented and tested, having user settable thresholds for back curvature during lifting and sitting.

CONCLUSIONS: Results demonstrate that with a minimal set of accelerometers and EMG channels, which can be processed digitally, the device sounds an alarm when the subject has performed movements classified as potentially harmful.



Angles calculated from accelerometers and SMART system. Accelerometers were placed of the level of the inferior scapula and S2/3. The performed movement was flexion with a straight back and lifting a 4.1 kg box

EFFECTS AND MECHANISMS OF MYOFEEDBACK TRAINING IN FEMALES WITH WORK-RELATED NECK-SHOULDER COMPLAINTS

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AIMS: Prognostic cohort studies in patients with neck-shoulder pain related to work (WMSD) or a trauma (WAD; Whiplash Associated Disorder) demonstrate that ambulant myofeedback treatment (Mfb) based on the Cinderella principle may be beneficial. Pain intensity, disability, and muscle activation levels decrease whereas muscle relaxation increases after 4-weeks of Mfb. However, these studies were characterised by limited power, short follow-up, absence of control groups and a lack of options to enable evaluation of the underlying working mechanism of Mfb. Therefore, a Randomised Controlled Trial was performed to further explore the effects of and mechanisms behind Mfb.

METHODS: Seventy-nine female computer workers reporting work-related complaints in the neck-shoulder region were recruited (mean age 51±5.7y; height 1.67±6.5m; weight 70±10kg). Participants were randomly assigned to either a Mfb or an Ergonomic counselling (EC) group. In both groups, subjects received four weeks of treatment during which they were visited at their work place by a therapist once a week. The ergonomical aspects of the work place were evaluated during the first visit and possible improvements were discussed. The remainder visits consisted of further discussions on ergonomical aspects, last week activities, and discomfort scores using a standard manual. Subjects assigned to the Mfb group received additional myofeedback training and the results of this training were discussed during the weekly visits at the work place.

Measurements prior to (T1), immediately after 4-weeks treatment (T2), and at 3 and 6 months follow-up (T3 and T4), focused on pain intensity in neck, shoulders and upper back, and disability. Upper trapezius muscle activation patterns were assessed using sEMG during rest and computer-related tasks. Coping strategies

and fear-avoidance beliefs about work and physical activities were measured as potential factors related to outcome after treatment. Analysis focused on the effect of treatment on pain intensity, disability, and muscle activation patterns using multi-level analyses techniques, and on the identification of prognostic factors for success and the mechanisms of treatment both using multiple regression-analyses.

RESULTS and CONCLUSIONS: Pain intensity and disability levels significantly decreased after 4 weeks Mfb. This effect remained after 3 and 6 months follow-up but no difference was observed in outcome between Mfb and EC. Muscle activation and muscle relaxation showed some changes after treatment, but this was neither significant nor different between Mfb and EC. Regression analysis indicated that subjects with high levels of ignoring pain sensations at baseline were more likely to benefit from Mfb than from EC. Based on this, it can be hypothesised that Mfb makes subjects more attentive to their pain sensations and is thus especially beneficial for a particular group of patients. Changes in pain intensity and disability after treatment appeared to be unrelated to changes in muscle activation and muscle relaxation levels. Further research is needed to explore to what extent these changes are related to coping strategies and fear-avoidance beliefs. Better insight in the working mechanisms is necessary to further enhance the effects of myofeedback in subjects having neck-shoulder complaints.

EFFECTS OF TASK STRESS ON KEYING FORCE, MUSCLE ACTIVATION AND PERFORMANCE IN COMPUTER WORK

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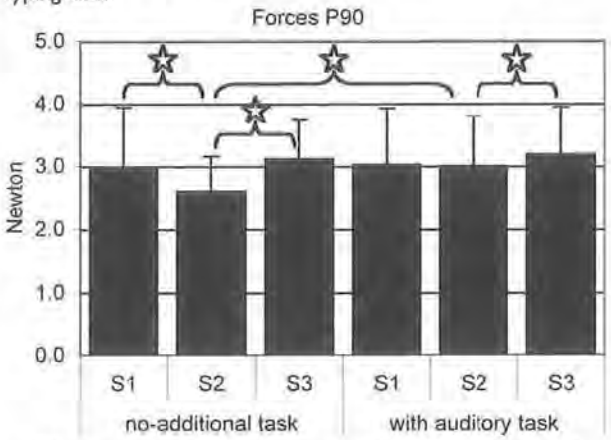
AIMS: Computer use has been identified as a risk factor for musculoskeletal disorders (Gerr et al. AJIM 41: 221-235 2004). Although the etiology of these disorders is not fully understood, several risk factors such as force, precision and task stress have been identified. Common types of task stress in computer work are high concentration demands and high time pressure. The aim of this study was to gain insight into the effects of typing speed and mental pressure on performance and load on the upper extremity during keyboard work. Concentration demands were manipulated by means of an auditory short-term memory task and time pressure was manipulated by typing speed.

METHODS: Ten subjects (5M,5F) performed 6 typing tasks with a duration of 5 minutes each. The typing tasks were performed as a combination of 3 typing speeds (subjects preferred speed (S2), 10% slower (S1) and 10% faster (S3)), combined with 2 mental pressure conditions (with or without an additional auditory short-term memory task). The keyboard was placed on a single-axis custom designed force plate (subjects were unaware of the force measurement). Forces were measured and peak values for individual key strokes were determined. The 50th and 90th percentile of these peaks during each condition were calculated. Muscular activity of several upper extremity muscles was measured by means of surface electromyography (EMG). EMG data were normalized to the maximal voluntary excitation (MVE). The 10th, 50th and 90th percentile of the Amplitude Probability Distribution were calculated. Number and length of EMG Gaps were calculated. The number of errors per 100 characters was counted.

RESULTS: Interaction effects of typing speed and the memory task were found in the key stroke forces. In the single task, forces were lower at the preferred speed (S2). At this speed, forces were lower without than with the memory task. In Figure the 90th percentile (P90) of key stroke forces are presented. Effects of speed on EMG were mainly in line with the effects on force. However, the double task led to lower P10 EMG values and more EMG gaps. Length of gaps did not differ between the conditions. Number of errors increased with typing speed and was higher with the memory task.

CONCLUSIONS: Deviations from prefered typing speed coincide with higher upper extremity loads. Unexpectedly, introduction of a double task yielded lower static EMG levels and more EMG gaps, probably due to short interruptions of the typing task.



*P90 of key stroke forces during typing. S1: 10% slower than S2; S2: preferred speed; S3: 10% faster than S2. *: significant ($p<0.05$)*

FATIGUE DURING TEST CONTRACTIONS AMONG WORKERS WITH AND WITHOUT TRAPEZIUS MYALGIA BEFORE AND AFTER WORK

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AIMS: Work related muscle disorders in the neck/shoulder area remain a major concern in repetitive stressful jobs. The aim of the present study was to reveal whether a simple test contraction can separate workers with and without trapezius myalgia. Low-level static test contractions have proven successful to reveal fatigue following low force work tasks [1]. Therefore, the present study investigated standardized test contractions [2] among workers with and without trapezius myalgia.

METHODS: Female workers age 30-60 years with (MYAL, n=14) and without (CON, n= 6) myalgia in their trapezius muscle participated. Myalgia was identified based on standardized clinical procedures. On the experimental day the subjects relaxed during a resting period (minimum 40 min) before they performed a 1 min test contraction with bilateral 90 degrees arm abduction (TEST1). During the subsequent approx 4 hrs the subjects performed a repetitive manual task (pegboard) as well as a stress task (colour-word-test) with their dominant side for the CON and with the most affected side for the MYAL. Subsequently, the test contraction was repeated (TEST2). Bipolar surface EMG recording from the upper trapezius muscle were analysed from the dominant/affected side during the two contractions. The background noise level was as a mean (SD) for all 20 subjects 3.4 (1.2) μV and was quadratically subtracted individually for each participant; thereafter, RMS as well as MPF was analysed for mid 56 s of each contraction. A straight line was fitted for each recording of which the initial value (ini) as well as the slope was calculated.

RESULTS: No differences in initial values for RMS were found between the two groups; however, MPF was lower in the MYAL group compared to the CON group in both TEST1 and TEST2. Further, for the MYAL group the slopes showed significantly increased RMS in TEST1 and in TEST2 and significantly decreased MPF in TEST2. For the CON group the slope showed significantly decreased MPF only in TEST2 (see Table).

CONCLUSIONS: Significant differences in initial MPF values were identified between workers with and without trapezius myalgia in TEST1 as well as TEST2. Also, for the MYAL but not the CON group a tendency of fatigue was demonstrated during

TEST I. Further, after repetitive and stressful working periods the same test revealed fatigue for the MYAL group (increase in RMS and decrease in MPF) while in the CON group only a decrease in MPF was seen. In combination the test contractions allow to separate between groups of workers with and without myalgia.

Mean (SD) values	RMS ini (μV)	RMS slope ($\mu V \cdot s^{-1}$)	MPF ini (Hz)	MPF slope ($Hz \cdot s^{-1}$)
TEST1 CON (n=6)	25 (9)	0.020 (0.072)	92 (10)	-0.038 (0.083)
TEST2 CON (n=6)	34 (11)	0.009 (0.030)	90 (10)	-0.059* (0.054)
TEST1 MYAL (n=14)	33 (14)	0.050* (0.070)	79 (10)	-0.033 (0.062)
TEST2 MYAL (n=14)	37 (13)	0.060* (0.068)	78 (9)	-0.050* (0.045)

[1] Blangsted AK, Sjøgaard G, Madeleine P, Olsen HB and Søgaard K. Voluntary low-force contraction elicits prolonged low-frequency fatigue and changes in surface electromyography and mechanomyography. J Electromyogr Kinesiol 2005: 138-148, 2004.

[2] Mathiassen SE, Winkel J and Hägg GM. Normalization of surface EMG amplitude from the upper trapezius muscle in ergonomic studies - A review. J Electromyogr Kinesiol 5: 197-226, 1995.

T20.P01
AN INFLUENCE OF GLENOID GEOMETRY ON ISOMETRIC SHOULDER STRENGTH DURING ONE-HANDED ABDUCTION

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AIMS: Laboratory strength analyses provide information about total body strength but do not indicate what elements of the joint of upper extremity effect strength performance. This study was conducted to test whether glenohumeral geometry, as measured through MRI scans, is correlated with upper arm strength.
METHODS: The isometric shoulder strength of 12 subjects during one-handed arm abduction in the coronal plane, in a range from 5° to 30°, was correlated with the geometries of their glenoid fossae. Seven parameters describing the glenohumeral joint geometry in the coronal plane were identified as having expected influence on shoulder strength (Fig.1). In addition to these, a new geometric parameter, named the area of glenoid asymmetry (*AGA*), was considered to reflect the concavity-compression mechanism as well as the inclination of the glenoid surface. The *AGA* was expressed as the cross-sectional area in the coronal plane that results from multiplying the height of the glenoid fossa (*c*) by difference between the upper (superior) and lower (inferior) depths of the glenoid (*a-b*) which represent margins of the glenoid bone.
RESULTS: As a result of the high correlation between the *AGA* and mean force and mean moment (0.80, $p \leq 0.01$ and 0.69, $p \leq 0.05$, respectively) at the glenohumeral joint in a coronal plane, the *AGA* was distinguished as a factor having influence on shoulder strength when an arm was abducted in a range from 5° to 30°.
CONCLUSIONS: The inclusion of anatomical parameters in shoulder exertion strength reveals that strength relates not only to muscles contributing to the generation of joint moment but also to ligament and joint contact forces. The geometrical parameter (*AGA*) distinguished in the shoulder strength analysis will help to modify physical strength standards, which are still too high as reflected in the frequency of recorded shoulder injuries.

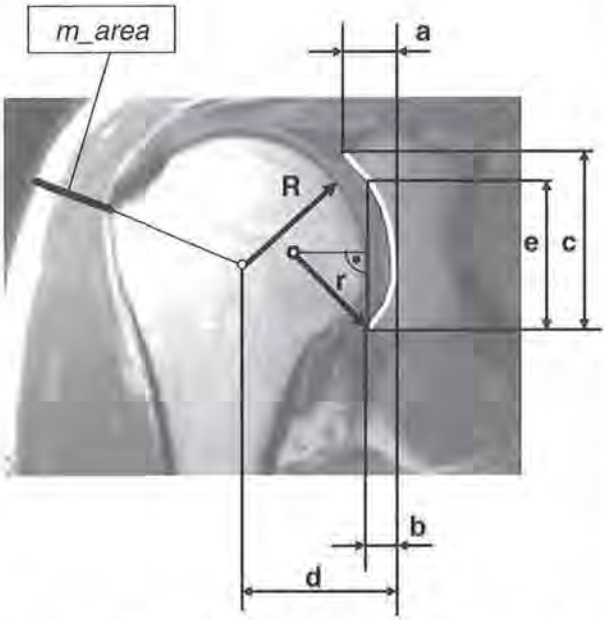

Figure 1. Geometric description of the glenoid concavity of the shoulder joint.

T20.P02
ASSESSMENT OF ERGONOMIC RISK IN LUMBER GRADERS, A REPETITIVE MONO-TASK SAWMILL POSITION

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AIMS: The objective of this study is to determine quantitatively the physical exposures involved in performing the lumber grader position, input those quantified demands into existing risk assessment methodologies, and compare risk assessment output to retrospective history of musculoskeletal injury and discomfort reported. In the forest products manufacturing sector lumber graders have a high incidence of compensation board claims.
METHODS: 29 industrial workers performing the lumber grader position were assessed in 3 sawmill facilities. Surface electromyography was used to determine percentage of maximum voluntary contraction required to maintain a representative board in a job simulated positions taken to demand peak force from the wrist flexors and pronators. Motion at the wrist was assessed with a pre-calibrated bi-axial and uni-axial Biometrics™ electrogoniometer. Risk assessment methodologies used (RULA, REBA, strain index, OCRA, HAL) were calculated based on the methods presented in their primary literature. Retrospective history of injury was determined through a review of workers compensation data.
RESULTS: Review of compensation board statistics revealed Lumber Graders have a high incidence of musculoskeletal injury in the upper extremity. Application of a body part discomfort index revealed that 59% of the subjects evaluated reported greater then moderate discomfort (greater then 4 on a scale of 0 to 10) in the task dominant upper extremity. The lumber grader job was observed to require an average of 10% of maximum voluntary contraction during an average of 34 repetitions per minute. Average velocity and accelerations employed to turn the boards were 125 degrees/sec and 293 degrees/sec^2 respectively. Dynamic forces required to perform each repetition were calculated to average 54 Newtons. Repetitions require peak forearm and wrist ranges of motion which account for 67% and 45% of total active range of motion respectively. Average daily repetition rates by facility were calculated to be as high as 15,613 and as low as 7,115. Risk assessment findings and their ability to predict reported discomfort varied according to technique used and variables input. Variables observed to effect level of risk attributed to the task included posture criteria selected (average posture vs. average peak posture vs. peak posture) and exertion criteria selected (% MVC vs. Borg rating of perceived exertion). Sensitivity and positive predictive values ranged from 0.63 to 1.0 and 0.47 to 0.97 respectively depending upon assessment procedure and varaible combinations input.
CONCLUSIONS: The use of quantified physical demands in the calculation of ergonomic risk assessments increases the assessment's reliability. The comparison of risk assessment output between methods to history of injury and report of discomfort, and within methods using differing criteria for the variables considered, allows us to gain insigth into the validity of the procedures in this application.

T20.P03
EFFECTS OF OCCUPATIONAL EXPOSURE TO ELECTROMAGNETIC FIELDS ON MENTAL HEALTH

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BACKGROUND & OBJECTIVE: In psychological studies exposure to electromagnetic field is one of the hazardous factors, which has adverse effects on mental health. Exposure to electromagnetic field due to daily use of electricity makes this study so important.

The goal of this study was to determine the relationship between psychological symptoms and occupational exposure to electromagnetic field among workers at High Voltage Substations.
METHOD: Sampling included 103 workers exposed to electromagnetic fields. The prevalence of psychological symptoms was evaluated among electrical workers and the SCL90-R questioner completed during an interview. The control group was not occupationally exposed to electromagnetic fields or not residence of transmission line.
RESULTS: This study indicates increased symptoms including depression; anxiety, hostility, paranoia, interpersonal-sensitivity, and obsession-compulsion were observed among exposed workers. A significant relationship was observed between the exposure of electromagnetic field and psychological symptoms.
CONCLUSION: Exposure to electromagnetic field increased the risk of disorders in susceptible workers. For mental disorders, especially depression, the cognitive therapy is suggested.

Key words: Psychology, Electromagnetic fields, and Occupational Exposure.

T20.P04
LOCALIZATION OF INNERVATION ZONES IN FOREARM EXTENSOR MUSCLES. A METHODOLOGICAL STUDY

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AIMS: This study provides information about the localization of innervation zones (IZs) in *extensor digitorum communis* (EDC), *extensor carpi ulnaris* (ECU), *extensor carpi radialis* (ECR) muscles and about the quality of surface electromyographic (sEMG) signals detected from them. Since these muscles are involved in a number of work-related neuromuscular disorders, it is of interest to standardize the procedure for sEMG electrode positioning, in order to extract accurate and repeatable estimates of signal amplitude, spectral variables and muscle fibres conduction velocity (CV).
METHODS: Eight healthy subjects (4 F, 4 M), aged 27.7±4.4 years (mean±SD), participated in the study. Subjects' skin was prepared by gentle local abrasion using abrasive paste and was cleaned with water prior to application of surface electrodes, in order to minimize skin impedance. Subjects were asked to sit on a chair with back erected, the forearm on a table laying in complete pronation, and the elbow flexed at 90°. Reference lines were drawn on subjects' skin on the basis of anatomical landmarks to properly localize the muscle: lateral epicondyle - centre of the wrist (EDC), lateral epicondyle - top of the pisiform bone (ECU), lateral epicondyle - junction between the bases of the first and the second metacarpal bone (ECR). Myoelectric signals were detected from each muscle during selective contractions, using 16 electrode linear arrays with decreasing inter-electrode distance (IED: 10 mm, 5 mm, 2.5 mm), placed parallel to reference lines (that is to fibre direction). After a first acquisition with the 10 mm IED array, exactly on the same forearm zone, the 5 mm IED array was applied two times, then the 2.5 mm IED array was applied four times (overall, seven recordings for each muscle of each subject). The use of this three arrays allowed to get subsequent zooms of the first recording to localize IZs by visual analysis of raw signals. The cross-correlation coefficient (CC, %) between consecutive double differential signals was adopted as a measure of quality of CV estimate. Each signal triplet among those acquired with arrays of 5 mm and 2.5 mm IED was classified as follows (being I the best class): I) $2 \le CV \le 8$ m/s and $75 \le CC \le 100$, II) $2 \le CV \le 8$ m/s and $60 \le CC < 75$, III) $8 < CV \le 12$ m/s and $60 \le CC \le 100$. For each of the three muscles and each subject, the best signal triplet was selected to provide the CV value.
RESULTS: At least two IZs were detected in ECR muscle, three IZs both in EDC and in ECU muscle. The most recurrent IZ for each muscle was selected and called *principal IZ* (pIZ). All muscles showed a large inter-subject variability of pIZ position. The best triplet was found in class I for the three muscles in almost all subjects. In one single case (ECR, 5 mm IED array) it was found in class III. The pIZ of each muscle was localized (mean±SD) at 45.7±7.2% of EDC reference line length, at 50.1±6.3% of ECU reference line length, and at 27.7±7.0% of ECR reference line length. EDC best acquisition zone was often found distally with respect to pIZ, ECR best acquisition zone often found proximally with respect to pIZ, whereas ECU best acquisition zone can be localized either proximally or distally with respect to pIZ. On the base of triplet classification and inter-subject variability of pIZ position it was possible to order the three muscles (starting from the best one) as follows: EDC, ECU, ECR. CV estimate (averaged between subjects and muscles) was found equal to 4.6±0.8 m/s.
CONCLUSIONS: If arrays are properly placed on forearm extensor muscles, it is possible to obtain reliable CV estimates (CC>75%) both with a 5 mm IED and a 2.5 mm IED, especially for EDC muscle. It is not possible to give exact references about best electrode location zone for any of the three muscles for different subjects.

T20.P05
SEMG RECORDINGS FROM THE FOREARM MUSCLES DURING ISOMETRIC CONTRACTIONS AT DIFFERENT EFFORT LEVELS

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AIMS: This study provides information about muscle activation at different levels of effort and myoelectric manifestations of fatigue during isometric contractions of the *extensor carpi radialis* (ECR), the *extensor digitorum communis* (EDC) and the *extensor carpi ulnaris* (ECU). Amplitude and spectral variables of surface electromyographic (sEMG) signals were studied.
METHODS: Ten healthy male subjects, aged 28.7±3.5 years (mean±SD), participated in the study. The procedure for optimal electrode positioning followed the findings described in [1]. Each muscle was firstly investigated during a selective contraction: signals were acquired with an eight electrode linear array (5 mm inter-electrode distance, IED) placed parallel to muscle reference line (that is to fibre direction). The recording location where signals provided conduction velocity (CV) in the range 2-8 m/s and the highest correlation coefficient (CC) (not lower than 60%) was considered as the *optimum recording location* for the selected muscle. On each of these zones an adhesive linear array with eight electrodes (5 mm IED) was then applied. Each subject was asked to exert two isometric wrist extensions without lateral rotation while keeping the fingers relaxed, in order to avoid activation of finger extensor muscles. Visual feedback of the exerted torque level was provided. Firstly, the subject was asked to extend his wrist according to an increasing step-wise torque profile: 10%, 20%, 40%, 50% and 80% of maximum voluntary contraction (MVC), with each step lasting 3 s. After three minutes of rest the subject was asked to extend his wrist at 50% MVC constant torque and to sustain that level up to exhaustion. Average rectified value (ARV), mean power frequency of the EMG signal spectrum (MNF) and muscle fibre CV were estimated.
RESULTS: During both the step-wise and the endurance contractions, ARV relative contribution of EDC to wrist extension decreased with respect to the ARV of ECR and ECU muscles. In the endurance contraction EDC muscle showed a significantly greater value of CV with respect to ECU ($p<0.03$) and ECR ($p=0.056$). Rates of change of ARV, MNF and CV were computed to study myoelectric manifestations of fatigue. ECR showed greater amplitude and spectral changes with respect to EDC and ECU. In all the three muscles ARV values at the 50% MVC step were found greater than ARV values estimated at the beginning of the endurance contraction. ECR CV value at the 50% MVC step was found smaller than CV value estimated during the endurance contraction at the same time (nine seconds after the beginning).
CONCLUSIONS: In both contraction modalities an unbalanced sharing of the load among the three muscles and a greater fatigability of ECR with respect to EDC and ECU were observed. Within the step-wise contractions, the more the torque level increases the more ECR and ECU muscles are involved, whereas within endurance contractions ECR activation level is greater

than ECU, which is greater than EDC. The observed EDC CV value higher than ECR and ECU CV values is probably due to both crosstalk from these two muscles and EDC different motor unit recruitment strategy. EMG signal amplitude was found to be influenced by muscle activity preceding the instant of variable estimation, even in absence of fatigue.

[1] M. Signorino, F. Mandrile, A. Rainoldi, "Localization of innervation zones in forearm extensor muscles. A methodological study", XVI ISEK Congress 2006, Turin, Italy.

T20.P06
TRUNK MUSCLE RECRUITMENT WHILE LIFTING IN A MOVING ENVIRONMENT

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AIMS: Commercial fishing, cargo and passenger shipping, as well as offshore oil and gas production are essential industrial activities in Canada, as well as other parts of the world. Mariners have to concentrate on maintaining balance as well as be prepared for motion-induced interruptions while performing work-related tasks, such as lifting. The purpose of this study was to examine the changes in trunk muscular activity of persons performing a lifting activity while exposed to simulated ships motion compared to those collected under stable, laboratory conditions.
METHODS: Nineteen healthy male subjects volunteered to participate in this study and were asked to perform repeated bi-manual symmetrical lifts (6 lifts.min^{-1}) while bilateral muscle activity of four selected trunk muscles were assessed. 10kg and 15kg loads were lifted through a vertical displacement of 750mm. The articulation between the mass and the handle was made by either a solid metal column (i.e. stable load) or a series of chain links (i.e. unstable load). A ship motion simulator was employed to produce three different platform motions during which the participants lifted loads. The platform motions where described as pitch, roll and quartering seas. Muscles were sampled at 1000 Hz by an eight channel portable bipolar surface electromyography (EMG) collection unit. The electrodes were placed bilaterally on the erector spinae (located at the level of the fourth and fifth lumbar vertebrae), external obliques (located at the midpoint between the ASIS and naval), latissimus dorsi (located 2 cm below the inferior angle and 3 cm distally), and trapezius (located 2 cm lateral of the midpoint between C2 and the acromion processes) muscles. Maximum voluntary contractions (MVC) were collected for each muscle and were repeated prior to the beginning of each experimental session. The raw EMG signals were full-wave rectified and low-pass filtered at 4 Hz (second order butterworth filter). The maximal voluntary contraction (MVC) values were used to normalize the EMG signal. The mean and maximum %MVC values were compared across floor motions (4) and loads (4) using a repeated measures ANOVA.
RESULTS: As expected there was a load effect, with the 15 kg conditions requiring more maximal and mean EMG activity. Suprisingly a difference in floor motions existed only between the laboratory (no motion) and the pitch motion conditions. Greater mean and maximum muscular activity was required of the left erector spinae, left and right latissimus dorsi, and the right trapezius muscles during simulated pitching sea conditions.
CONCLUSIONS: The results suggest that the trunk required more stability when lifts were performed in the simulated pitching sea condition. Although it was hypothesized that a difference in muscular activity would be evident in all motion conditions compared to the laboratory condition, the pitch condition was seen to be the most difficult for participants to complete without a motion-induced interruption. A better understanding of the muscular efforts required when working in moving environments would be beneficial in establishing appropriate ergonomic lifting guidelines, which to date are non-existent.

T20.P07
COMPUTER RELATED UPPER LIMB MOTOR PATTERNS BY USING DIFFERENT POINTING DEVICES

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AIMS: The Computer Related Upper Limb Disorder represents a frequent cause of disability in the industrialized countries. The upper limb is one of the district that can be involved by using wrongly devices such as pointing devices (mouse, trackball, stylus). Computer related upper limb disorders are often cause of refund claim by workers who use mouse for many hours per day. In literature, many studies deal, with contrasting results, with the negative influence of the mouse on the upper limb, but there are no studies assessing the influence of ergometrically different pointing devices on the upper limb muscles. The aim of our study was to assess the muscular activation during a standardized "path" using different pointing devices (mouse, trackball, stylus).
METHODS: We enrolled 15 healthy subjects and we studied their muscular pattern when using different pointing devices. We performed a superficial EMG to several proximal and distal muscles of upper limb during a standardised pattern. This study was performed at the laboratory of Neurophysiopatology at Università Cattolica Del Sacro Cuore, and at the Don Gnocchi of Rome.
RESULTS: The motor pattern of upper limb by using the different point ing devices was significantly different. In some cases we observed mainly activation of distal muscles (forearm and hand) while in other cases we observed even activation of proximal and limb girdle muscles.
CONCLUSIONS: Our results are relevant either because they give useful information in order to understand upper limb muscular activation using different devices or because they can be used to assess strategies aimed to prevent upper limb diseases in computer operators.

T20.P08
EVALUATION OF ELECTRODE POSITION EFFECT ON CV ESTIMATION ON UPPER TRAPEZIUS MUSCLE

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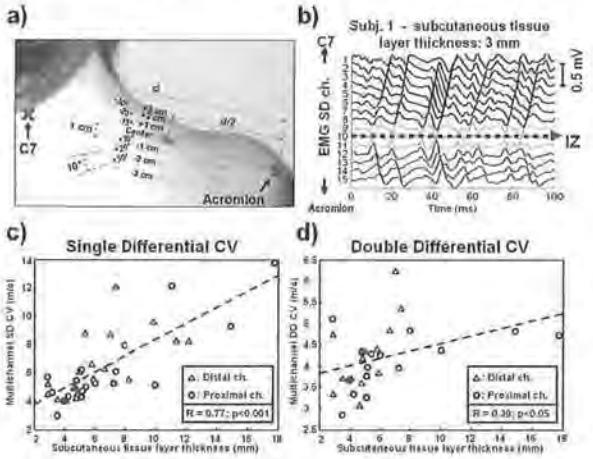
AIMS: The objectives of the study were: 1) the evaluation of the EMG signal detected from the upper trapezius muscle of young and elderly subjects; 2) the evaluation of the effect of subcutaneous tissue layer thickness on EMG parameters; 3) the evaluation of the effect of array inclination and position with respect to the anatomical landmarks on the estimation of muscle fiber conduction velocity
METHODS: Twenty volunteer subjects, 8 males and 12 females, (mean±SD; age: 30±14 years; height: 169±9 cm; weight: 65±11 kg; BMI: 22±3 kg/m^2) participated to the study. The muscle studied was the dominant upper trapezius (the dominance was assessed with the Edinburgh test). The dominant side was the right side for all subjects. EMG signals were detected using a linear array of 16 electrodes with 5 mm interelectrode distance in single differential configuration and during voluntary contractions. Force was measured with a load cell. Each subject was asked to perform a low level contraction at 20% of the maximal voluntary contraction (MVC) for each of the 13 different positions of the linear array (see Figure a).
At the end of the EMG measurement session, the subcutaneous tissue layer thickness was measured with an ultrasound scanner in the midpoint of the segment C7-Acromion.
For each epoch ARV, RMS, MNF and MDF were computed over each channel, CV for the two sides of propagation was computed with a multichannel algorithm (on the "Proximal channels" and the "Distal channels" respectively, see Figure b) when possible

using two different spatial filters (single and double differential).
RESULTS: The EMG parameters did not show statistically significant dependence either from the array position or from its orientation. The CV estimation depended on the spatial filter, with higher values with the single differential signals (Figure c,d). The comparison of EMG parameters extracted from the two sides of propagation of the upper trapezius muscle fibers showed slight differences in EMG amplitude (resulting higher laterally) and CV estimation (with higher values medially). The differences seem to be related to the different subcutaneous tissue thickness detected on the two sides of propagation, which was thinner laterally, as predictable from anatomy book images.
A positive correlation was observed between the CV estimates and the subcutaneous tissue layer thickness (Figure c,d) especially with the single differential signals which did not remove completely the non travelling components on the EMG signals.
CONCLUSIONS: The main finding of the present study is that the subcutaneous tissue layer thickness causes overestimation of CV with both SD and DD signals. However, the array positioning and orientation on upper trapezius muscle is not critical, when the average value of global parameters is computed only on the array portion between IZ and tendons. Thus, an accurate identification of the IZ position reduces the variability of EMG parameters due to array position and orientation.



a) Representation of the array position on the upper trapezius muscle.
b) Example of EMG signal detected with the array positioned on the line between C7 and acromion.
c,d) Scatter plot of the subcutaneous tissue layer and the Conduction Velocity computed with a multichannel algorithm using single and double differential signals respectively.

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The number in brackets is the number of presentations.

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What is 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.

Every two years, these scientists gather at a Congress of ISEK to share advances and knowledge in the broad field of Electrophysiological Kinesiology.

It spans such key topic areas as:

- muscle and nerve properties
- motor units
- physiological modeling
- control of movement
- motion analysis
- posture
- joint biomechanics
- muscle fatigue
- sports and exercise
- measures of human performance
- neuromuscular diseases
- rehabilitation
- electrical stimulation

When did ISEK begin?

The Society was born on August 13, 1965 when its founder J.V. Basmajian, S. Carlsöö, B. Jonsson, M.A. MacConnaill, J. Pauly and L. Sheving met and agreed to the formation of a small society of electrophysiological kinesiology. Soon afterwards, the first Council of ISEK was elected, including its first president, J.V. Basmajian.

The 1st International Meeting of ISEK took place in Montreal in 1968 where some 70 members participated, and the Constitution and Rules of ISEK were adopted. Since that time, a total of ten International Meetings or Congresses have been held, typically with several hundred participants in attendance. In addition to the exchange of scientific views, past meetings have produced such important contributions as the guidelines for reporting the units, terms, and standards for EMG research, and the establishment of the Society's official journal, the Journal of Electromyography and Kinesiology (JEK), in the fall of 1990.

Who are the members of ISEK?

Approximately 500 members are currently active in the Society, representing over 30 countries from around the world. The society's membership consists of a broad range of professions from the biomedical sciences, engineering, physical therapy, physical education, motor control, as well as other disciplines having an interest in research and clinical applications of electrophysiology and kinesiology. Its membership and leadership have included many of the pioneers in these fields.

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 ISEK Council

The Current (2004-2006) ISEK Council consists of the following positions (elected for 2 years):

President

Catherine Disselhorst-Klug
Biophysical Measurement Techniques/Applied Medical Engineering, Helmholtz Institute
Paulwelsstr. 20
D- 52074 Aachen, Germany

Vice President

Toshio Moritani
Graduate School of Human and Environmental Studies, Kyoto University
Yoshida Nihonmatsu, Sakyo-ku, Japan

Past-President

Hermie Hermens
Roessingh Research & Development
University of Twente
Roessinghsbleekweg 33, The Netherlands

Secretary

Richard Baratta
Louisiana State University Health Sciences Center
Department of Orthopedic Surgery, Bioengineering Laboratory
2025 Gravier St., No. 400
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Treasurer

Paolo Bonato
Department of Physical Medicine and Rehabilitation
Harvard Medical School, Spaulding Rehabilitation Hospital
125 Nashua Street, Boston, USA

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Roberto Merletti

Laboratorio di Ingegneria del Sistema Neuromuscolare, Dip. Elettronica, Politecnico di Torino

Torino, Italy

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Dario Farina

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Linda McLean

School of Rehabilitation Therapy

Queen's University

31 George Street, Louise D Acton Building

Canada

Leif Sandsjö

National Institute for Working Life

(affiliated to: Chalmers University of Technology)

Göteborg, Sweden

The Birth of ISEK

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. They were J.V. Basmajian of Canada, S. Carlsøø and B. Jonsson of Sweden, M.A. MacConaill of Ireland, and J. Pauly and L. Scheving of the USA. On that date, on August 13,1965, this group agreed to found ISEK, the International Society of Electrophysiological Kinesiology. There and then Dr. Scheving took a photograph of the birth of ISEK which appeared on the cover of the June 1973 Newsletter.

Dr. Basmajian volunteered to gather a list of persons to invite as charter members. With the help of the founding group, his list had, by November 1967, grown to 231 scientists in 21 countries.

The First Business Meeting

At the Biomechanics Symposium in Zurich, August 22, 1966, some 25 of the members were available for a business meeting. They decided on a more formal structure and authorized an interim executive board consisting of J. Basmajian (President), B. Jonsson (Secretary), and S. Carlsøø (Treasurer). The other members of the board included J.E. Pauly, M. Hebbelink (Belgium) and T. Tokizane (Japan). J. Basmajian, as interim president was asked to organize a first international meeting in Montreal, Canada, in 1968 and to prepare plans for a formal society. Later T. Simard was recruited to assist as local program organizer, and, having moved to Montreal, H. Ladd also began to work on the conference.

The First ISEK Conference

The 1 st International Meeting of ISEK took place in the Queen Elizabeth Hotel in Montreal, August 24-25,1968. More than 70 members participated. During the two days, 30 scientific papers were presented. Most of them were published as Proceedings of the Meeting in a separate volume of the Journal of Electromyography and Clinical Neurophysiology.

On August 25, the first official Business Meeting of ISEK was held with about 50 members present. The following subjects were discussed during that meeting.

1. Election of the council

2. The "Constitution and Rules of ISEK" were adopted at the meeting

3. It was suggested by W.D. Mcleod (Canada) that ISEK should organize a "Committee for Standards and Definitions". W. D. McLeod was asked to be the chairman of such a committee

4. E. R. Tichauer (USA) suggested that ISEK would try to cooperate with other organizations relating to electromyography, biomechanics and kinesiology. The suggestion was unanimously adopted

The first regularly elected council of ISEK (for four years) was: J.V. Basmajian (President), J. Joseph (Vice President), B. Jonsson (Secretary), S. Carlsøø (Treasurer), F. Buchthal (Denmark), V. Janda (Czechoslovakia), J.E. Pauly (USA), N.E.J. Rosselle (Publications Secretary) (Belgium), T. Tokizane.

ISEK Report on EMG Standards

After many years of debate on EMG standards and units, in August of 1980, ISEK published a long needed report on "Units, Terms, and Standards in the Reporting of EMG Research". This publication is now being reviewed with an updated expected in the near future.

The Journal of Electromyography and Kinesiology

At the beginning of 1993 the edition of Journal of Electromyography and Kinesiology was entrusted to Butterworth-Heinemann. The editors were from that time on Toshio Moritani, Moshe Solomonow and Willemien Wallinga. The journal appeared regularly, 4 issues per year. ISEK encourages membership and its publications, newsletter and journal seek to provide a medium whereby the international community can exchange ideas and scientific information. The world wide distribution of members sharing the common bond of scientific advancement and teaching of electrophysiology, biomechanics and kinesiology provides a tremendous potential for the exchange of meaningful information.

Compagnia di San Paolo
Supports the development of new equipment and co-sponsors specific projects

Fondazione CRT
Supports the development of new equipment and co-sponsors specific projects

European Community
Supported the RTD Projects "Neuromuscular assessment in the Elderly Worker" (NEW) and "On ASymmetry In Sphincters" (OASIS) and supports "Cybernetic Manufacturing Systems (CyberManS)"

European Space Agency
Supports the Projects "Microgravity Effect on Skeletal Muscles" (MESM) and "Resistance Training Using Flywheel Technology"

Italian Space Agency
Supports a project on Ostheoporosis and muscle atrophy

Regione Piemonte
Supports specific projects and sponsored dissemination of results and technology transfer through training courses and the DIADI Project

Politecnico di Torino
Funds doctoral fellowships and provides laboratory and office space and services

COREP
Provides administrative services

LABORATORIO DI INGEGNERIA DEL SISTEMA NEUROMUSCOLARE E DELLA RIABILITAZIONE MOTORIA
TORINO

The Centre for Biomedical Engineering is a joint venture of Politecnico di Torino and the Consortium for Research and Continuing Education (COREP).

The Centre has activated its first Laboratory for Engineering of the Neuromuscular System and Motor Rehabilitation with the primary objective of promoting research and continuing education at the national and international level.

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THE LABORATORY FOR ENGINEERING OF THE NEUROMUSCULAR SYSTEM AND MOTOR REHABILITATION (LISiN), CENTER FOR BIOMEDICAL ENGINEERING, POLITECNICO DI TORINO

Prof. Roberto Merletti, Director

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The activities of LISiN concern the study of the Neuromuscular System mainly through the analysis of surface EMG signals generated by voluntary or electrically elicited muscle contractions. In this field LISiN has established collaborations with research institutions in Italy and abroad.

LISiN was the Coordinator of the European RTD project *Neuromuscular assessment in the Elderly Worker (NEW)* and partner of project *On ASymmetry In Sphincters (OASIS)*. LISiN is also Coordinator of the German-Italian Project *Technologies for Anal Sphincter analysis and Incontinence (TASI)*, partner of the EU project *Cybernetic Manufacturing Systems (CyberManS)*, coordinator of the ESA project *Microgravity effects on human skeletal muscle investigated by surface EMG and mechanomyogram* and is partner of the ESA Project *Resistance training using flywheel technology.*

The mission of LISiN is: a) to promote aggregation and convergence of interests and activities of European academic and clinical researchers in the field of Neuromuscular Engineering and Movement Analysis, b) to integrate local, national and international activities, promote dissemination of knowledge and develop methodological standards by means of courses, seminars and integrated research and teaching activities and, c) to promote technology transfer to clinical institutions and small companies.

In the first ten years of activity LISiN researchers organized fifteen courses for health personnel and ten international seminars and workshops, wrote most of the textbook *Electromyography: Physiology, Engineering and Non-invasive Applications* (IEEE press and J. Wiley), published over 100 papers in international journals, a chapter in the CRC book *Biomedical Technology and Devices*, the item "*Electromyography*" in the J. Wiley Encyclopedia of Electrical Engineering and over sixty presentations at international meetings. LISiN researchers participated to a study on high altitude physiology at the National Research Council's Piramide Laboratory in Nepal, to a study on knee muscles at the University of Queensland, Australia, to a study on EMG decomposition at the National Institute of Occupational Health in Copenhagen and carried out research projects at the Universities of Aalborg in Denmark, of Maribor in Slovenia, of Nantes and Nice in France. Researchers and professors from USA, Canada, Europe, South Africa and Australia spent at LISiN sabbatical periods ranging from two weeks to six months.

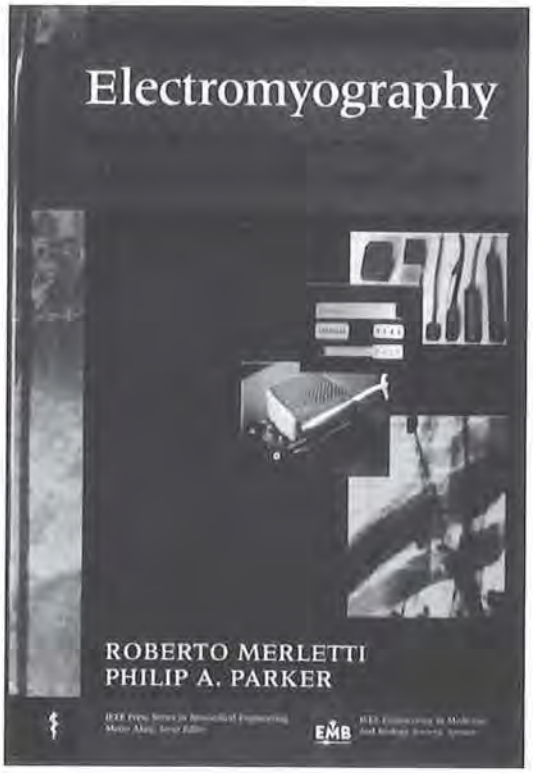
The main products developed by LISiN are: a) modular systems for measurement of isometric torque of human joints, b) multichannel systems for acquisition and processing of surface EMG in static and dynamic conditions, c) electrode arrays for acquisition of EMG from skeletal and pelvic floor muscles, d) multichannel programmable stimulator, e) mathematical models for generation of EMG signals suitable for teaching and research purposes and for testing algorithms, f) multimedia teaching instruments about surface EMG techniques. LISiN cooperates with a few Small and Medium Enterprises for the manufacturing and commercialization of these products and holds four patents concerning them. Finally LISiN has translated and made available in Italy the *European Recommendations for Surface Electromyography* published within the European Project on *Surface EMG for Non Invasive Assessment of Muscles (SENIAM)*.

LISiN offers interesting opportunities for interdisciplinary research in an international environment in the fields of electromyography and movement sciences. LISiN offers opportunities for inexpensive housing to visiting scientists and researchers.

The research projects carried out at LISiN are described in the publications and in the Annual Reports that are available at no charge from Prof. R. Merletti (Dept. of Electronics, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129, Torino, Italy, tel +39-011-5644137 or +39-011-4330476, fax. +39-011-5644099 or +39-011-4330404, E-mail: roberto.merletti@polito.it.

Most material is also available from the WEB site **www.lisin.polito.it**.

The following books are part of the LISiN research and dissemination activities.
They represent the state of the art in the fields of surface EMG and Biomedical Engineering in Exercise and Sports (from: www.lisin.polito.it).



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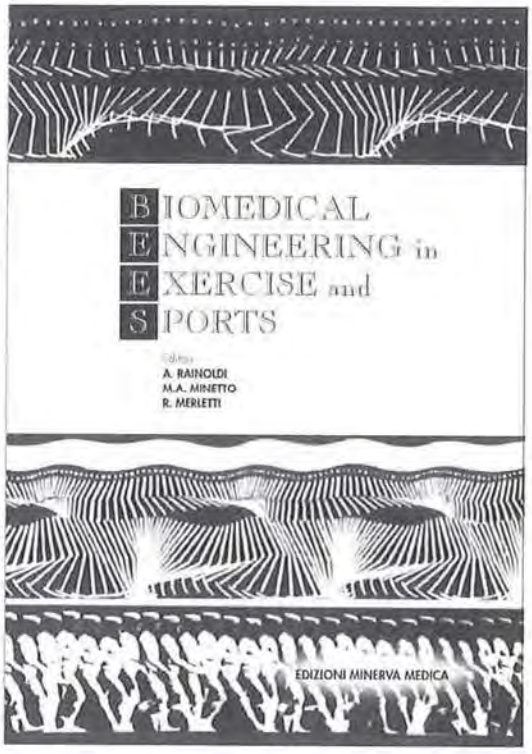

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