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International Society of Electrophysiology and Kinesiology

UNIVERSITY COLLEGE DUBLIN

JUNE 30th – JULY 2nd 2018

UCD DUBLIN

ABSTRACTS
PRESENTATIONS

ABSTRACTS KEYNOTES

Saturday, 30th June – Monday, 2nd July

KEYNOTE LECTURE 1 BASMAJIAN AWARD LECTURE

SATURDAY JUNE 30TH, 8:30-9:30

Roger M. Enoka, University of Colorado Boulder, USA

Decomposition of Interference EMG Signals Recorded with Surface Electrodes

BACKGROUND
As the final common pathway of the motor system, the motor unit transmits an activation signal and transforms it into contractile activity. The nervous system controls muscle force by modulating motor unit recruitment and rate coding. One approach to deciphering the control signal, therefore, is to estimate the times at which motor neurons discharge action potentials. Such recordings begun in the 1920s and typically involved intramuscular electrodes. Relatively recent advances in technology, however, have made it possible to obtain comparable information with surface electrodes that do not involve invasive procedures.

THE TECHNOLOGY
The approach requires a device to detect the signals with surface electrodes and an algorithm to decompose the recordings into the discharge times of single motor units. The detection systems comprise multiple channels of information, ranging from a 4-probe electrode to grids of electrodes (e.g., 6 x 6, 5 x 13, 8 x 8) that are known as high-density array electrodes. The two most commonly used algorithms include one that is proprietary and another that is shared and involves convolutive blind source separation.

VALIDATION
Some of the findings obtained with this new technology (decomposition of surface EMG signals), however, are challenging basic concepts about motor unit physiology that were established with classic intramuscular techniques. The purpose of the talk is to compare the findings obtained with the different decomposition approaches to those derived from intramuscular recordings. The approach will involve comparing the results for five characteristics of motor unit activity: peak discharge rates, rate coding during rapid contractions, saturation of discharge rate during ramp contractions, rate coding during force oscillations, and adjustments in recruitment and rate coding during fatiguing contractions.

CONCLUSION
The comparisons will indicate that there are substantial differences in the veracity of the different decomposition approaches, which underscores the need for caution when evaluating the results obtained with these methods.

KEYNOTE LECTURE 2

SATURDAY JUNE 30TH, 14:00-15:00

Todd A. Kuiken, Northwestern University and Shirley Ryan Ability Lab, USA

Building Bionics

This talk will describe the development of targeted muscle reinnervation (TMR) as a clinically practical tool for improvement of the control artificial limbs. Some of the early neurophysiology will be presented. Next, the clinical concept will be discussed along with other methods currently used to get access to neural control signals. targeted sensory reinnervation (TSR) will be shown and briefly discussed. Some hardware that has been developed to enhance the function of TMR and amputee function in general will be presented. Finally, new data showing the effect of TMR on minimizing amputee pain will be presented and discussed.

KEYNOTE LECTURE 3

SATURDAY JUNE 30TH, 17:30-18:30

Apostolos P. Georgopoulos, University of Minnesota, USA

The Role of Motor Cortical Inhibitory Mechanisms in Movement Specification and Control

In this lecture I will discuss theoretical considerations and experimental evidence from neurophysiological and functional neuroimaging studies related to the role and importance of inhibitory mechanisms in the motor cortex in motor control. The basic idea is that the amount of inhibitory drive in the motor cortex determines the speed and accuracy of the movement.

References

Mahan MY, Georgopoulos AP (2013) Motor directional tuning across brain areas: Directional resonance and the role of inhibition for directional accuracy. Front Neural Circuits 7:92.
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Georgopoulos AP, Carpenter AF (2015) Coding of movements in the motor cortex. Curr Opin Neurobiol 33C:34-39.
Merchant H, Georgopoulos AP (2017) Inhibitory mechanisms in the motor cortical circuit. In Handbook of Brain Microcircuits (2 ed), GM Shepherd, S Grillner (eds), Oxford University Press, pp 67-73.

KEYNOTE LECTURE 4

SUNDAY JULY 1ST, 8:30-9:30

Cathy Stinear, University of Auckland, New Zealand

Prediction of motor recovery after stroke: advances in biomarkers

Recovery of motor function after stroke is crucial for regaining independence. However, making accurate predictions of a patient's motor recovery and outcome is difficult when based on clinical assessment alone. Clinical assessment, neurophysiological and neuroimaging biomarkers of corticomotor structure and function can help to predict both motor recovery and motor outcome after stroke. The combination of biomarkers can provide clinically useful information when planning the personalised rehabilitation of a patient. These biomarkers can also be used for patient selection and stratification in trials investigating rehabilitation interventions that are initiated early after stroke, potentially improving their sensitivity and efficiency.

KEYNOTE LECTURE 5

SUNDAY JULY 1ST, 14:00-15:00

Walter Herzog, University of Calgary, Canada

Individual Muscle Forces in Human Movement

Humans move through the coordinated actions of muscles. Muscles are activated in a controlled manner by the central nervous system, and these activations are refined by sets of excitatory and inhibitory pathways that, in turn, depend on a variety of inputs from muscles, joints, skin, ligaments, tendons, etc. Once muscles receive a certain time-dependent activation, the force they produce depends on a variety of variables: the fibre type distribution, the force-length, force-velocity, and history-dependent properties, the muscle's size and structure, elastic elements, and tendons, to mention just some of the more obvious variables. To date, it has been impossible to measure the individual forces exerted by muscles in humans, although forces in agonistic groups, such as the Achilles tendon, have been measured, but with no external verifiable and accurate validation. Similarly, predictions of individual muscles forces in humans cannot be trusted to be accurate, as such predictions in animal studies with verifiable forces have been unanimously unsuccessful.
In my lecture, I would like to revisit some of the problems associated with the prediction of muscle forces. These problems will be focused on:

- (i) The force-sharing among synergistic muscles
- (ii) The determination of basic in vivo human muscle properties
- (iii) The insight we might gain by not only using external force magnitudes but also force direction in the prediction of individual muscle forces, and
- (iv) The problem of changes in force capacity of muscles when activated within their synergistic group.

Force-sharing among synergistic muscles will be demonstrated by measurements of individual muscle forces in the cat hind limb. Regular force-sharing patterns within the ankle extensor muscles will be discussed. I will demonstrate that force-sharing among muscles is highly task-dependent, but for a given task, is highly variable.
Basic, in vivo human muscle properties will be examined based on the force-length and force-velocity relationships, emphasizing the need for distinguishing between the mechanics of the muscle-tendon unit and those of the fascicles.
The effect of external force direction will be illustrated on the example of the cat hind limb and human cycling. Specifically, I will illustrate how the direction of force application in cycling restricts the muscle synergies that can be employed.
Finally, I would like to demonstrate, using direct muscle force measurements and individual muscle controlled activation of the rabbit knee extensor muscles, that the force capacity of a muscle when activated in isolation is different from that of the same muscle activated in the same manner and for the same contractile conditions within its synergistic group.
In summary, studying muscle coordination and synergistic force-sharing in human movement is difficult and requires novel technologies that allow for an accurate determination of the variable individual muscle forces. Unfortunately, there is no such technology in sight at this moment. The major breakthroughs in this area will continue to come from carefully executed animal experimentation where activation, muscle forces and muscle properties can be measured readily.

KEYNOTE LECTURE 6

MONDAY JULY 2ND, 8:30-9:30

Peter Brown, University of Oxford, UK

Developing Closed-loop Deep Brain Stimulation for the treatment of Parkinson's Disease and Essential Tremor

For decades we have had cardiac pacemakers that adjust their pacing according to demand and yet therapeutic adaptive stimulation approaches for the central nervous system are still not clinically available. Instead, to treat patients with advanced Parkinson's disease or medically refractory Essential Tremor we stimulate the basal ganglia or thalamus with fixed regimes, unvarying in frequency or intensity. Although effective this comes with side-effects and in terms of sophistication this treatment approach could be compared to having an air-conditioning system on all the time, regardless of temperature. This talk will describe the steps being taken to improve deep brain stimulation by controlling its delivery according to the state of pathological activity in key brain circuits. One can think of this like adding thermostatic control to an air-conditioning system to avoid over heating while avoiding excessive cooling and unnecessary power loss. But to labour this analogy still further, how can we sense 'overheating' in the brain?

Evidence is growing that the 'overheating' in Parkinson's disease and Essential Tremor takes the form of the excessive synchronisation between oscillating neurons. Some degree of transient synchronisation is thought to be beneficial during neural processing by way of improving signal to noise ratios. However, excessive synchronisation, even if transient, reduces the information coding capacity of the system, impairing processing, and can even overflow down to the spinal cord and drive limb tremor.

Recordings in patients with Parkinson's disease confirm bursts of oscillatory synchronisation in the basal ganglia centred around 20 Hz. The bursts of 20 Hz activity are prolonged in patients withdrawn from their usual medication and the dominance of these long duration bursts negatively correlates with motor impairment. Longer bursts attain higher amplitudes, indicative of more pervasive oscillatory synchronisation within the neural circuit. In contrast, in heathy primates and in treated Parkinson's disease bursts tend to be short. Accordingly it might be best to use closed-loop controlled deep brain stimulation to selectively terminate longer, bigger, pathological beta bursts to both save power and to spare the ability of underlying neural circuits to engage in more physiological processing between long bursts. It is now possible to record and characterise bursts on-line during stimulation of the same site and trial adaptive stimulation. Thus far this has demonstrated improvements in efficiency and side-effects over conventional continuous stimulation, with at least as good symptom control in Parkinsonian patients.

But what can be done if it is difficult to directly record the abnormal oscillatory synchrony in neural circuits or, although we can record, we do not have an obvious pattern of neural dysfunction? Here we can use surrogates like peripheral tremor to infer the concurrent state of brain circuits and apply machine learning techniques to identify neural patterns that dictate the need for stimulation. These and other approaches can be exploited to achieve adaptive deep brain stimulation that delivers the minimum intervention necessary to control symptoms for each patient and at each instant in time.

KEYNOTE LECTURE 7 – INTERNATIONAL SOCIETY OF BIOMECHANICS (ISB) SPONSORED LECTURE

MONDAY JULY 2ND , 14:00-15:00

Taija Finni, University of Jyväskylä, Finland

Lack of muscular activity as a major health problem

Activation of skeletal muscles is essential for locomotion and motor tasks but muscles have an important role also in maintenance of healthy metabolism. The most dramatic deteriorating effects of muscle inactivity are seen in bed rest -related chronic conditions. However, also for healthy people, lack of sufficient daily muscle activity has been shown to initiate unwanted adaptations increasing the likelihood of metabolic and cardiovascular risk factors (Hamilton 2017). During normal daily life, healthy people's thigh muscles are inactive about 70% of the day and average EMG activity level is less than 5% of maximal voluntary isometric contraction (Tikkanen et al 2013, Pesola et al. 2014). Even in persons meeting physical activity recommendations muscle inactivity time during a day correlates adversely with blood lipids (Pesola et al 2015). Therefore, combatting sedentary behavior and increasing daily muscle activity persists to be one of the grand challenges of our days.

In this keynote I will discuss about possible consequences of sedentariness and lack of sufficient physical activity and review studies reporting daily muscle EMG.

References

Hamilton MT. 2018. The role of skeletal muscle contractile duration throughout the whole day: reducing sedentary time and promoting universal physical activity in all people. J Physiol. 15;596(8):1331-1340.

Tikkanen O, Haakana P, Pesola AJ, Häkkinen K, Rantalainen T, Havu M, Pullinen T, Finni T. (2013) Muscle Activity and Inactivity Periods during Normal Daily Life. PLoSOne 8(1): e52228.

Pesola AJ, Laukkanen A, Haakana P, Havu M, Sääkslahti A, Sipilä S, Finni T. (2014) Muscle inactivity and activity patterns after sedentary-time targeted RCT. Med Sci Sports Exerc 46,11: 2122-2131.

Pesola AJ, Laukkanen A, Tikkanen O, Sipilä S, Kainulainen H, Finni T. (2015) Muscle inactivity is adversely associated with biomarkers in physically active adults. Med Sci Sports Exerc. 47 (6), 1188-1196.

WORKSHOPS
Friday, 29th June

W 2.1 HDSEMG: PROPER USE AND APPLICATIONS

A. Aranceta-Garza[1], B. Afsharipour[2], S. Soedirdjo[2], R. Merletti[3],
[1]University of Strathclyde, [2]Shirley Ryan Ability Lab, Northwestern University, [3]Lab. for Engineering of the Neuromuscular System (LISiN), Politecnico di Torino, Italy,

HDsEMG and EMG imaging. The distribution of electrical potential on the skin above a muscle and evolving in time is a sequence of analog images (a movie) that can be sampled in time and in space by a grid of electrodes. The spatial sampling should satisfy Nyquist criterion and is critical because of the physical size of the electrodes. Consider electrodes of dimeter *d* and interelectrode distance IED = $e < d$ (that is a spatial sampling frequency of *1/e* samples/m). To satisfy Nyquist criterion it should be $1/e > 2f_{max}$ where f_{max} is the highest harmonic (in space) above noise level. Image interpolation, as well as further processing, can be performed ***only*** if Nyquist criterion is satisfied. The transfer function of a single differential electrode pair is provided in Fig 1. An additional factor to consider is the finite size of the electrode grid which implies truncation in space and power "leakage" in the spatial frequency domain [2].

The issue of noise. In normal life activities, the RMS value (in time) of the sEMG of postural muscle may be close to the amplitude of the noise generated by the electrode-skin interface and by the electronics. Fig. 3 shows an example of noise recorded from an electrode array applied to the erector spinae of a relaxed subject. The noise recorded from a piece of pigskin has very similar features.

Applications. Fig. 4 and 5 show two clinical applications to the assessment of the biceps brachii muscle.

Conclusions. Proper use and application of HDsEMG are opening up novel quantitative approaches to neuromuscular investigation in preventive and occupational medicine as well as in rehabilitation and sports sciences. The training of PTs and movement scientists in this field is a condition to manage, orient and control such evolution, and to integrate technological and clinical research. The role of international scientific societies, such as ISEK and ISB, as well as of national associations, is fundamental to achieve this goal. The current competences and expertises of clinical operators in this field are insufficient and the gap between technological advances in research labs and applications in the health delivery systems is widening.

This situation must be corrected urgently by means of technology transfer and educational initiatives.

References

[1] R. Merletti, D. Farina, *Surface electromyography: physiology, engineering, and applications*. IEEE Press and J. Wiley, 2016, ch 3 and 5. ISBN: 978-1-118-98702-5.

[2] B. Afsharipour, S. Soedirdjo, R Merletti, "Two-dimensional surface EMG: the effects of electrode size, interelectrode distance and image truncation" Submitted.

[3] A. Russo, R. Merletti, "Spatially correlated noises among electrodes in HDsEMG" XXVI Congress of ISB, July 2017, Brisbane, Australia.

[4] F. Jahanmiri-Nezhad, X. Li, W.Z. Rymer, and P. Zhou, "A practice of caution: spontaneous action potentials or artifactual spikes?" J. of Neuroengin. and Rehab. 2015, doi: 10.1186/1743-0003-12-5.

[5] B.Afsharipour, S. Chandra, W.Z. Rymer, and N.L.Suresh, "Alteration of surface electromyogram patterns after botulinum toxin injection in stroke survivors" Program No. 502.11/KK9. 2017 Neuroscience Meeting Planner, Washington, DC. Society for Neuroscience, 2017. Online.

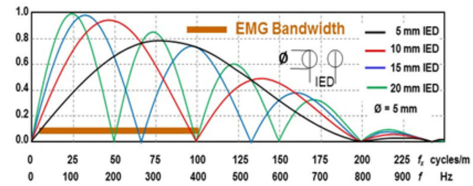

Fig. 1. Plots of the magnitude of the transfer function of an electrode pair, having diameter of *5* mm and four IEDs aligned with the fiber direction, versus the spatial frequency f_x and the temporal frequency $f = v\, f_x$ (for $v = 4\ m/s$) where v is the MUAP propagation velocity The amplitude spectrum of the signal, and therefore its shape, are strongly modified by the electrode pair geometry [1].

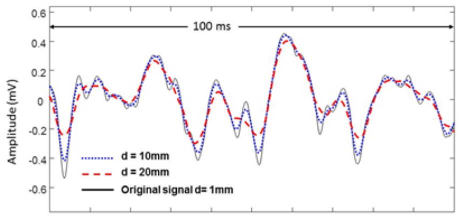

Fig. 2. Example of monopolar signal detected with a circular electrode of diameter d=1 mm and then filtered by the electrode transfer function for d= 10 mm and d= 20 mm. Large electrodes imply large IEDs which in turn cause additional filtering as described in Fig. 1. Interpolation of images obtained with widely spaced and large electrodes does not allow recovery of the original image and any further processing would provide misleading results.

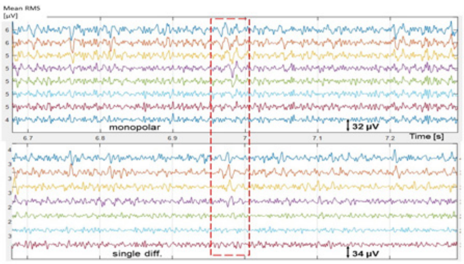

Fig. 3. Noise recorded from one column of an electrode grid applied to the erector spine muscle of a relaxed subject (prone in bed) [3]. This noise is similar to that recorded from pieces of pigskin and shows amplitude and spectral drifts that may alter the estimates of sEMG features. The dashed red line outlines highly correlated transients that are not originated in the muscle, are present in recordings from pig skin, and deserve further investigation [3,4]. The RMS values of the individual channels are indicated on the left.

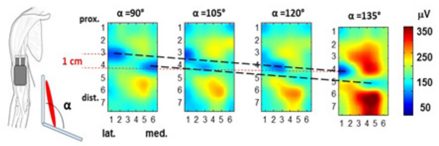

Fig. 4. Single differential maps of sEMG detected over the biceps brachii while the elbow extends from 90° to 135° resisting the action of an external force (eccentric contraction). The innervation zones of the short and long head move by about 1 cm indicating a muscle lengthening of about 2 cm.

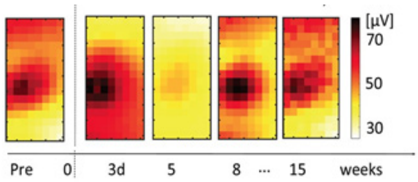

Fig. 5. Spatial patterns of monopolar RMS maps of a spastic bicep brachii (chronic stroke survivor) before and after botulinum toxin injection from 3 days to 15 weeks. Monitoring the evolution of spasticity and the effect of antispastic treatments is an important application of sEMG imaging [5].

W 5.6 FUTURE PERSPECTIVES AND NEW TRENDS OF SEMG RELATED TO REAL LIFE SETTINGS

R. Merletti[1], A. Russo[1], A. Aranceta-Garza[2],
[1]Lab. for Engineering of the Neuromuscular System (LISiN), Politecnico di Torino, Italy, [2]University of Strathclyde

2D and 1D sEMG signals. The surface EMG (sEMG) is a two-dimensional (2D) analog signal (image), representing the instantaneous intensity of the signal on a region of skin above the muscle(s) of interest. This image is sampled in space by an array of electrodes as is done in the case of ECG on the chest or EEG on the scalp.

A relatively large number of electrodes (as for EEG) provides a spatially sampled map that is evolving in time (like a movie). The amplitude of the signal provided by each electrode or by each pair of electrodes can be estimated over a sequence of time intervals (e.g. the RMS over "epochs" ranging from 0.25 s to a few seconds) providing a new sequence of images describing the time course of the sEMG amplitude in space and in time. Both image types contain information far superior to that of a single electrode pair. The size of the electrode (diameter *d*) introduces an averaging in space and a low pass filtering in the spatial frequency domain. The interelectrode distance *e* introduces sampling in space at the frequency of 1/e samples/m which must be higher than the Nyquist rate. These requirements are relatively severe ($d < 3\text{-}4$ mm, $e < 5\text{-}6$ mm) but may be relaxed in clinical applications if no further processing (e.g. decomposition) is required ($d < 5\text{-}7$ mm, $e < 10\text{-}14$ mm); they apply also to linear electrode arrays and to a single electrode pair [1].

This technology has been used in research labs for about a decade and is becoming progressively easier to apply. Traditional sEMG (e. g. for gait or movement analysis) is based on bipolar signals which provide only information about the time course of the signal detected in a specific (often non representative) location.

Bottlenecks. With the exception of a few Countries and Doctoral Programs, and despite the availability of textbooks [2], neither the 2D nor the 1D approach is included in the curriculum offered within the degree of Physiotherapy or Movement Sciences. Technical complexity, cumbersome electrodes and cables are bottlenecks but wireless systems are rapidly taking over. Practical difficulties are partially due to technology but largely due to lack of teaching and training of the users. This results in lack of demand, leading to limited marked and commercial interest. Too many potential users are waiting for commercial products rather than contributing to develop them.

Future applications and trends. Current trends involve the use of integrated sEMG and Inertial Measuring Units (IMU) [3]. Future applications involve the use of large arrays included in sleeves covering an entire limb and carrying, on board, the signal conditioning and wireless transmission electronics [4]. Systems transparent to ultrasound will have an important role in physiological investigations [5]. Applications span from preventive and occupational medicine to rehabilitation and sports. Fig. 1, 2 and 3 show the application of 2D arrays a) to the trapezius of a typist, b) to the erector spinae of a violinist sitting on two different chairs and c) to the right and left trapezius of a violinist in concert [6].

Conclusions. Preventive and occupational medicine as well as rehabilitation are undergoing a technological revolution that will allow easy monitoring of muscle activity, biofeedback control, proper training of the subjects/patients, and quantitative assessment of results, treatments and trainings. The training of PTs and movement scientists in the technological field is a condition to manage, orient and control such event.

References

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6. Russo A, Aranceta-Garza A., D'Emanuele S., Serafino F., Merletti R.HDsEMG activity of the lumbar erector spinae in violin and piano players: Comparison of two chairs. Submitted.

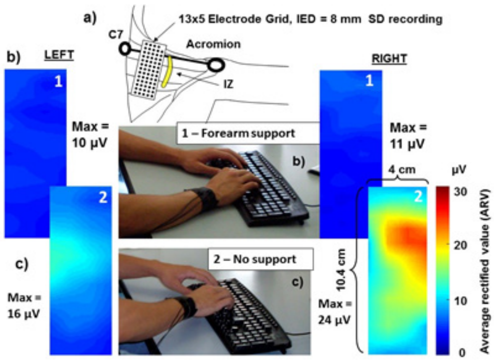


Fig. 1. Interpolated RMS maps from two electrode arrays applied to the right and left upper-middle trapezius of a typist with and without forearm support on the table. A simpler system can be used to warn the worker about unnecessary muscle hyperactivity.

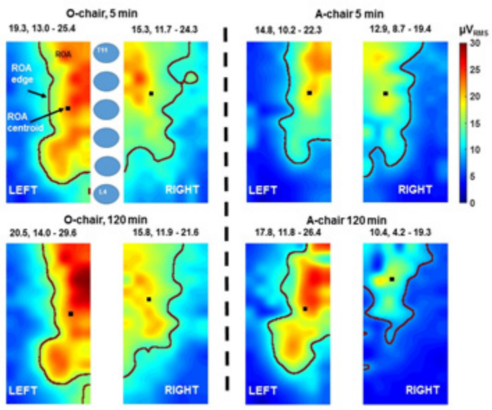


Fig. 2. Interpolated and segmented RMS maps from two electrode arrays applied to the right and left lumbar erector spinae of a violinist playing for 2 h while sitting on a standard orchestra (O) chair or on an alternative (A) chair. Mean and range of EMG values in space are indicated above each map.

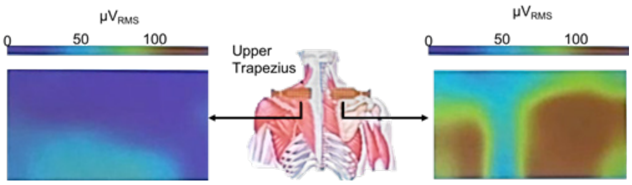
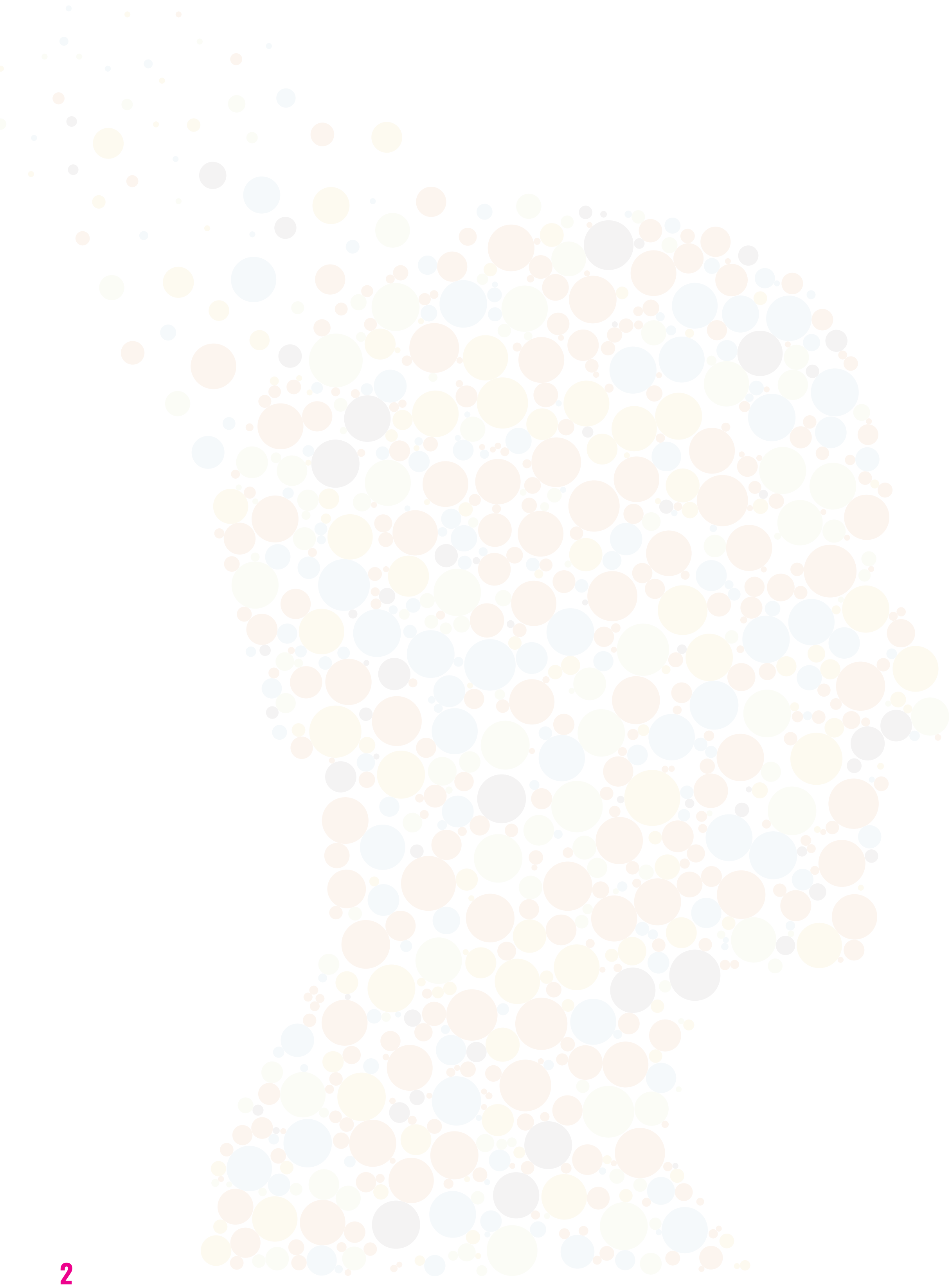


Fig. 3. Interpolated RMS maps of activity of the right and left upper trapezius muscles (epoch = 025 s) of a sitting violinist. The technique could be used to teach violin students to minimize muscle activity and reduce the likelihood of pain

ORAL PRESENTATIONS

Saturday, 30th June

SATURDAY JUNE 30TH



O1 REFLEXES & NEURAL PATHWAYS I

O1.1 Functionally relevant changes in interlimb and intralimb cutaneous reflex excitability from the hand during standing with stable versus unstable light touch

John E Misiaszek, Heather Hackett, Sydney Chodan
University of Alberta

BACKGROUND AND AIM: It is well established that postural sway is mitigated by light touch. Recently, we demonstrated that rapid displacement of a light touch reference leads to short-latency activation of ankle muscles and a pronounced sway of the body, suggesting that touch feedback from a single fingertip can trigger balance reactions. However, these responses were only observed following the first displacement, replaced subsequently by arm muscle activation. These findings suggest that sensory information used in balance control is flexible and can be quickly reweighted in a context-dependent manner. Electrical stimulation of cutaneous afferents from the fingers evokes reflexes in the ankle muscles. It is argued that these interlimb reflexes serve a role in co-ordinating the actions of the arms and legs, and are relevant for maintaining balance. If these interlimb cutaneous reflexes are involved in balance control, and in evoking touch-displacement balance corrections, then we expect these reflexes will be facilitated when touching a stable reference. In contrast, if the touch reference is unstable then we will not expect to observe facilitation of the reflex. The electrical stimulation of cutaneous afferents from the fingers also evoke intralimb reflexes in the muscles of the arm, which are argued to serve a role in regulating arm posture and may be of importance in the arm-tracking responses observed in our previous studies. Therefore, we expect that the excitability of the intralimb arm reflexes will adapt in concert with the interlimb reflexes when the response to the touch displacement switches from a balance reaction to an arm-tracking behavior.
Methods: Cutaneous reflexes from the median nerve were recorded in the leg and arm muscles of 12 healthy adult participants during each of three conditions: standing on foam with eyes closed a) without touch, b) while lightly touching (<1 N) a stable reference, and c) touching a reference that has been unexpectedly and repeatedly displaced.

Results: Middle latency cutaneous reflexes recorded in soleus (SOL) were significantly ($p<0.05$) larger when touching a stable reference (mean±sd; 4.78±1.57 %MVC) than when not touching a reference (1.00±1.05 %MVC) or when touching an unstable reference (1.07±1.16 %MVC). Reflexes in other leg muscles were not different. In contrast, middle latency cutaneous reflexes recorded in anterior deltoid (AD) were larger when touching an unstable reference (4.50±1.31 %MVC), compared to touching a stable reference (1.34±1.01 %MVC) or not touching (1.50±1.00 %MVC). Reflexes in other arm muscles were not different.

Conclusions: These findings indicate that light touch of an external reference influences the excitability of sensorimotor pathways depending upon the relevance of the contact to balance control. This highlights that sensory information used in balance control is flexible and can be quickly reweighted in a context-dependent manner.

O1.2 Impact of a sensory perturbation on somatosensory evoked potentials and motor learning for the non-dominant hand

Paul Yielder[1], Ryan Gilley[2], Bernadette Murphy[2]
[1]University of Ontario Institute of Technology, Deakin University, [2]University of Ontario Institute of Technology

BACKGROUND: The dominant limb favours feedforward control whereas the non-dominant limb favours feedback control, which is likely to affect the response to external perturbations during motor skill acquisition. Early somatosensory evoked potentials (SEPs), can be used to investigate differences in the processing of somatosensory input during motor skill acquisition. Sensory perturbations during learning may be an abrupt, one time stimulus as seen in visuomotor rotations, or a more continuous stimulus. Experimental pain induced by capsaicin is a continuous sensory perturbation, which improved a motor acquisition tracking task performed with the dominant limb, accompanied by differential changes in early SEP peaks. It is hypothesized that motor acquisition and learning and SEP peak amplitudes will be less affected by capsaicin for the non-dominant limb, as the increased reliance of the non-dominant limb on feedback control allows it to adapt more quickly to sensory perturbations.
Methods: 19 right hand dominant participants performed a motor acquisition-tracking task with their non-dominant (left) thumb. They were randomly allocated to an intervention group (N=9) who experienced cutaneous pain induced by application of capsaicin cream on the lateral aspect of the left elbow; or a control group (N=10) who had an innocuous control cream applied to the left elbow while during the task. The motor acquisition task traced a sinusoidal waveform, randomly varying in amplitude and frequency, with different complexity levels. SEPs were elicited via stimulation of the left median nerve at the wrist, prior to cream application, in the presence of the cream and after motor training, Motor performance was measured following the tracking task, and retention was measured 24-48 hours later.

Results: Both groups increased in performance accuracy over the course of training [$F(2,34)=41.04$,$p<0.0001$], and in the N24 SEP amplitude [$F(2,34)=5.25$, $p<0.01$], with no significant interaction between groups. The control cream group N24 increased by 44% ± 17% while the capsaicin group increased by 10%± 13%.
Discussion: As predicted, the non-dominant limb was less affected by the presence of a sensory perturbation induced by experimental cutaneous pain. Past studies with capsaicin applied to the dominant limb found that the N24 SEP peak decreased by 30% for the control group, suggested disinhibition in the cerebellar pathways to sensorimotor cortex, with no change in the capsaicin group. This study showed opposite changes for the non-dominant limb with the N24 increasing following motor learning, which may be indicative of the enhanced reliance of the non-dominant limb of feedback control, meaning that it did not need to first disinhibit to learn. This study suggests that SEP peaks may be useful biomarkers of differences in neural processing between the limbs, which can inform differences in rehabilitation strategies between the two limbs.

O1.3 Body position changes the amplitude of the H-reflex

Serpil Cecen[1], Imran Khan Niazi[2], Rasmus Nedergaard[2], Heidi Haavik[2], Kemal Turker[3]
[1]Marmara University, [2]New Zealand College of Chiropractic, [3]KOC University School of Medicine

BACKGROUND AND AIM: H-reflex has been used as a tool to study the effectiveness of the spindle primary afferent synapse on motoneurons under many circumstances including varying body postures. The results on the effect of body posture on the H-reflex varied considerably even though similar H-reflex protocols were used in these studies. Most previous studies used the tibial nerve stimulation and recorded the H-reflex response from the leg muscles. It is possible that such dramatically varying findings can be due to the following reasons: 1) not controlling the level of background muscle activity preceding the stimulus; 2) not normalizing the level of other receptor activity such as the receptors in the soles of the feet during standing or sitting; and 3) not normalizing the reflex findings to the stimulus intensity. The aim of this study therefore was to examine the changes in the H-reflex in varying body postures using a standardized approach, which attempts to minimize the confounding variables. The principle hypothesis was that the effect of the body posture on the H-reflex could be demonstrated only when all parameters that may influence the reflex are controlled stringently. In this approach, the only uncontrolled variable was the changes in body posture.

Methods: In the current study, we controlled all parameters that may influence the reflex. Each subject had their H-reflex and M-wave recruitment curves recorded in their right soleus muscle three times by stimulating the ipsilateral tibial nerve. This was done in three different body postures: while the subject standing on their left leg with the right leg loosely hanging to the side; sitting on a high chair without feet touching to the ground; and lying prone with the subjects' feet over the edge of the bench.
Results: The H-reflex curve relative to the M-wave curve did not change significantly in any of the body postures. However, the maximal H-reflex amplitude increased significantly in the prone position compared with the sitting ($P=0.02$) and standing positions ($P=0.01$). The background level of electrical activity of the soleus muscle did not significantly change during varying body postures.

Conclusions: Together, these findings indicate that the efficiency of the spindle primary afferent synapse on the soleus motor neuron pool changed significantly in the prone position as compared to sitting and standing positions. Given that we have controlled the confounding factors excluding the head position relative to the gravity and the receptors that may be differentially-activated at varying body postures such as the proprioceptors, it is concluded that the tonic activity from these receptors may presynaptically interfere with the effectiveness of the spindle primary afferent synapses on the soleus motor neurons.

O1.4 Static stretching of plantar flexors decreases mechanical reflex excitability as revealed by the Achilles tendon tap

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BACKGROUND AND AIM: It is well documented that muscle stretching reduces passive stiffness and stretch reflex activity (Guissard and Duchateau 2004, Avela et al. 1999), however the duration of general neuromuscular responses to stretching are less clear. Accordingly, the aim of this study was to analyze spinal reflexes and motor evoked potentials (MEPs) up to 10 minutes after passive stretching of plantar flexors.

Methods: Stretching (ankle dorsiflexion) was performed by means of an isokinetic dynamometer. Stretching duration was 1 min (2 x 30 sec) in the first experiment (EXP1, N=19), and 5 min (10 x 30 sec) in the second experiment (EXP2, N=17). The experiments included assessment of Achilles tendon tap reflex (TTR), H-reflex (HR) and MEPs at 120% of resting motor threshold, incorporating SEMG`s from soleus and tibialis anterior muscles. Each of the three neurophysiological tests included 15 (EXP1) or 12 (EXP2) stimulations. Three assessments were performed after stretching intervention: immediately after (post0), 5 minutes after (post5), and 10 minutes after (post10). Between the assessments subjects were requested to stand up for two minutes. For control the assessments were repeated without stretching in the same body position.

Results: Following 1 min stretching (2 stretches, EXP1) the TTR was strongly inhibited at post0 (-59%), but this effect faded out at post5. Linear regression of the 15 single TTR responses at post0 showed a slow recovery rate within the first 150 sec. HR was slightly increased at post0 (+18 %) and showed a fast recovery rate. There was no effect at post 5 and post10 in relation to control. No effect at any time point was found for the MEPs. Following 5 min stretching (10 stretches, EXP2) the TTR was strongly inhibited at post0 (-58%) and this effect persisted up to post5 (-16%). There was no effect at post10 in relation to control. HR was slightly increased at post0 (+16 %) but again no effects were found at post5 and post10. Also no effect at any time point was found for the MEPs.
Conclusions: The main finding of this study is a lasting (2 - 5 min) decrease in mechanical reflex excitability, as indicated by the TTR. Since no such effects were observed at HR and MEP, there is evidence for a decrease muscle spindle responsiveness to mechanical input. Various intervention-induced factors may reduce the discharge of muscle spindles such as inhibition of fusimotor drive via joint receptors (Sjölander et al. 2001), or formation of slack owing to time dependent viscosity (thixotropy) in intrafusal fibers (Proske et al. 1993). Taking into account the recovery time of the TTR (2 -5 min), stretch induced thixotropy appears to be more likely than alterations in fusimotor drive. Further studies, including longer stretch durations with repetitions over some days, are needed to reveal the onset and formation of long-lasting changes in reflex excitability.

O1.5 Multiple descending pathways may contribute to the response of the gastrocnemius to transcranial magnetic stimulation

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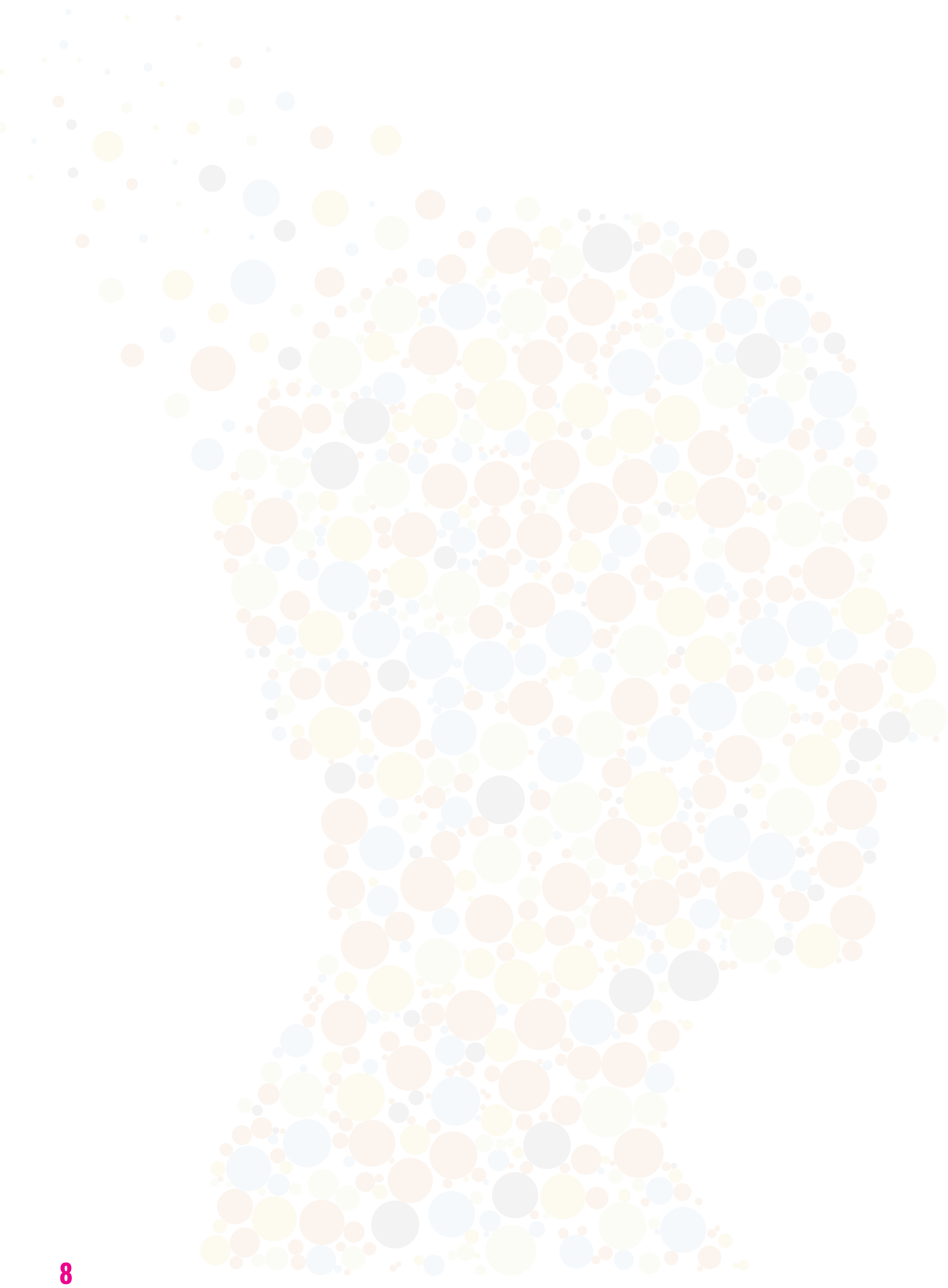
Background: In humans, independent movement of the hands and feet are predominantly controlled by the corticospinal tract, yet the postural demands that accompany these movements are mediated by non-corticospinal pathways in the brain stem. There is currently no method available to study non-corticospinal motor pathways in humans. The aim of this study was to determine whether neuromuscular responses to transcranial magnetic stimulation (TMS) in the lower limb contained components that were independently modifiable.

Methods: This study consisted of four experiments. Nine individuals with no history of neurological disorder or injury participated in Experiment 1 and five of those individuals also completed Experiments 2-4. All methods employed were approved by the University of Otago Human Ethics Committee (Health) (Approval H16/110). Protocol In all experiments, surface electromyograms (EMG) were recorded at 4 kHz. Exp 1: TMS was applied in a conditioning-test protocol, where the conditioning pulse produced a period of EMG silence of at least 100 ms. The test pulse was applied at intensities that represented 100, 110, 120 & 130% of threshold at 50 and 80 ms after the conditioning pulse. Ten stimuli were applied in each condition. Exp 2: Single or paired pulse TMS was applied over the optimal scalp location for eliciting first dorsal interosseous (FDI) responses. Paired stimuli were separated by either 50 or 80 ms. Exp 3: Single or paired pulse TMS was elicited gastrocnemius responses with participants seated or standing. Paired stimuli were separated by 50 ms. Exp 4: Electrical stimuli were used to elicit H-reflexes either alone, or following supra-threshold TMS by 50 or 80 ms. Data analysis Exps 1&2: The amplitude of the mean response was calculated for each condition and compared using a one-way repeated measures ANOVA (ISI). Exps 3&4: The amplitude of the mean response in each condition was calculated and compared using a two-way repeated measures ANOVA (ISI x POSTURE).

Results: In Exp 1 there was a significant effect of ISI on TMS response amplitude, in that an increase in the amplitude of the late part of the response was observed at 120 and 130% of active threshold when the stimulus was delivered 50 or 80 ms after a suprathreshold conditioning stimulus. A significant effect of ISI was also found for responses in the FDI in Exp 2, with a modest increase in response amplitude at an ISI of 50 ms and a decrease in amplitude at an ISI of 80 ms. Exp 3 identified a significant increase in the amplitude of the gastrocmenius response to TMS at an ISI of 50 ms. Exp 4 confirmed that the amplitude of the gastrocmenius H-reflex was significantly decreased at an ISI of 50 ms.
Conclusions TMS applied during small contractions induces responses with multiple components that are independently modifiable and modulate according to the level of postural instability. These results suggest the contribution of multiple pathways in response to TMS.



S1 SYMPOSIUM: HIGH DENSITY SURFACE EMG: A NON-INVASIVE RESEARCH TOOL AT THE TRANSITION TO CLINICAL APPLICATIONS

S1.1 High-density EMG: from the first ideas to a routine method in muscle electrophysiology

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Radboud University Medical Centre

The use of EMG signals for clinical purposes came up in the 1950´s with the work of the group of Fritz Buchthal [1] and got a further boost in the 1980´s because of the important work around another Scandinavian researcher, Erik Stalberg [2]. The early clinical applications and the present practice of muscle investigations were and still are almost exclusively based on different needle EMG techniques of recording and analysis. More recently, advanced possibilities to use the non-invasive surface EMG signal came up with the development of multi-channel surface EMG, especially versions with small inter-electrode distances from 3 up to 10 mm, high-density surface EMG (HD-sEMG). It acknowledges that a muscle is a three-dimensional structure, anatomically, but also functionally. The multi-channel surface EMG goes in fact back to the work of Gydikov and colleagues [4]. With one-dimensional array electrodes, motor unit action potential propagation could be followed along the muscle fibers. Later, two-dimensional grids were introduced, first by Masuda and colleagues [5]. It allowed the description of an EMG signal as a spatio-temporal phenomenon instead of a single point observation. An important technical prerequisite to make the technique versatile is the development of high common mode rejection amplifier systems that allow so-called monopolar recordings with respect to a common reference electrode [6]. Virtually, all post-hoc electrode montages can then be constructed to analyze different aspects of the signal, like e.g. the field of view into the muscle. A systematic review, already in 2006, evaluated the clinical applications of HD-sEMG [7]. Still, most studies are mainly in a stage of bringing important pathophysiological insights. It concerns muscle fatigue, motor neuron diseases, neuropathies, myopathies, spontaneous muscle activity like in ALS. But also detailed anatomical muscle information, like the complex system of facial muscles, can be extracted on the basis of the analysis of single motor unit activity. The above summary of applications reveals that algorithms to decompose the HD-sEMG signals into firing characteristics of single motor units is one of the largest challenges in the field. This symposium will give examples of the use of HD-sEMG gives insight in the present possibilities of the measurement and analysis of HD-sEMG signals, eventually providing a routine non-invasive clinical tool.

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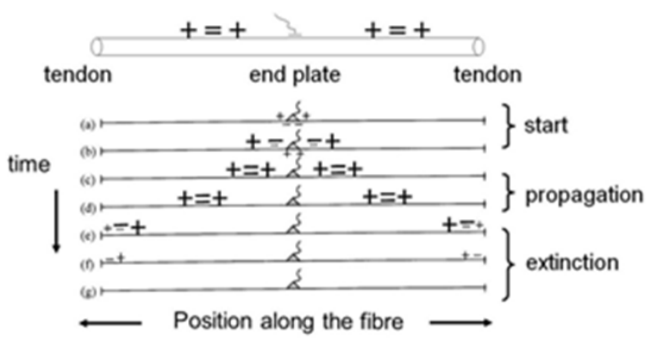

Figure 1: the life cycle of a triphasic muscle fibre action potential: start-up, propagation and extinction

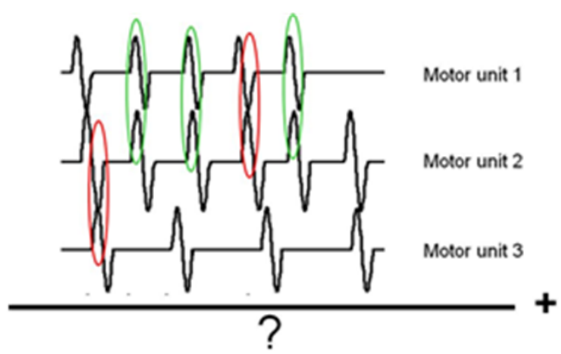

Figure 2: phase cancellation of motor unit action potentials: some phases add up (green), others cancel each other (red)

S1.2 Motor unit territory assessment: high-density and scanning EMG

Johannes van Dijk, Bernd Lapatki
University of Ulm

Application of high-density surface EMG for clinical usage is challenging because of the technical difficulties in handling the large amount of data and determining meaningful physiological variables. An important question that may be asked is whether the signals obtained from the skin surface are representative for the muscle as a whole? Moreover, if we can decompose the interference surface EMG signal into the contribution of individual motor units (MUs), up to what depth can this motor unit information be obtained? The answer to these questions will show us the limitations of the techniques that we use for clinical evaluations and science. Hence, the goal of this study was to determine the representativity and 3D characteristics of decomposed high-density surface EMG MUs. For this we used a novel scanning EMG approach using firing times of individual MUs obtained from the decomposed surface EMG of the masseter muscle. Moreover, as the masseter is a complex muscle, we wanted to compare our results with those obtained with intramuscular techniques. Hence, also two pairs of fine wires were inserted and the signals were decomposed. This way the validation of the firing times obtained with the CKC decomposition program (1) could also be assed for these relative long recordings. We recorded high-density surface EMG signals of the masseter muscle of 10 healthy volunteers. A monopolar scanning needle and two pairs of fine wires were inserted. During light contraction the scanning needle was retracted from the muscle by a stepper motor. The firing times of the surface signals and separately for the fine wire signals were used as triggers to obtain the MU territory, MU depth, territory length, electrical size and medio-lateral spatial distribution (2). The median rate of agreement between the MUs that were detected by both the surface and fine-wire signals was 91% while the sensitivity was 96%. Forty-three of the 190 surface decomposed MUs were also visible on the scanning needle. A total of 44 MUs were visible on the scanning EMG monpolar needle. Territory size was slightly (not significantly) larger for the scanned MUs based on surface EMG signals. MUs up to a depth of 17.8mm could be obtained. There was no correlation between MU territory size and depth. As the masseter is a highly complex organized muscle with many small motor units it was questionable if the surface EMG could obtain a representative sample. The current study shows that although very small and very deep units are inaccessible, high-density surface EMG allows obtaining a large sample of MUs with a large variety of sizes and depth.

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S1 SYMPOSIUM: HIGH DENSITY SURFACE EMG: A NON-INVASIVE RESEARCH TOOL AT THE TRANSITION TO CLINICAL APPLICATIONS

S1.3 On coherence between cumulative motor unit spike trains and NMF components of high-density electromyograms

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BACKGROUND AND AIM: Both Non-negative Matrix Factorization (NMF) [1] and Convolution Kernel Compensation (CKC) [2] methods aim to estimate the muscle excitation patterns, but differ substantially in the assumed data model. NMF typically rectifies the EMG signals and assumes multiplicative mixing model, whereas CKC builds on convolutive model and fully eliminates the motor unit action potentials (MUAPs) from muscle excitation estimates. Although both methods are used for more than a decade, the differences between their results have not yet been fully quantified and analyzed.

Methods: We used two arrays of 5x13 electrodes to record high-density EMG (hdEMG) signals from wrist flexors and extensors. Six healthy male subject performed repeated wrist flexions and extensions, whereat muscle forces (torque between 0 of 7 Nm) and wrist position were controlled and measured by Universal Haptic Device robot [3]. NMF [1] and CKC [2] methods were independently applied to the recorded signals and the identified components and MUs were classified into three different groups. Those with at least 90 % of energy during the flexion (extension) were put into the G1 (G3) group, whereas the remaining ones were classified into G2. Afterwards, we summed up components/MU spike trains in each group into cumulative NMF components and cumulative spike trains (CSTs), respectively. Finally, we calculated maximal coherence between the cumulative NMF components and CSTs in alpha, beta, gamma and delta bands.
Results: On average, 41 ± 17 (52 ± 23), 7 ± 14 (9.3 ± 12), and 52 ± 20 (39 ± 23) % of CST (NMF) energy was concentrated in G1, G2 and G3 groups. The maximal coherences in delta band were 0.77 ± 0.18, 0.3 ± 0.3 and 0.78 ± 0.12 for G1, G2 and G3, respectively. Coherences decreased to 0.34 ± 0.26, 0.03 ± 0.04 and 0.54 ± 0.18 in alpha band and to 0.27 ± 0.06, 0.04 ± 0.06 and 0.39 ± 0.15 in beta band (Figure 1).

Conclusions: We compared two popular methods for decomposition of surface EMG signals into muscle excitation patterns and showed that their results agree on global scale but differ substantially in several details. Potential reasons for reported low coherence values include negative impact of MUAP shapes and noise on NMF decomposition and limited number of identified MUs by CKC method.

ACKNOWLEDGEMENT: This study was supported by the Slovenian Research Agency (project J2-7357 and Programme P2-0041).

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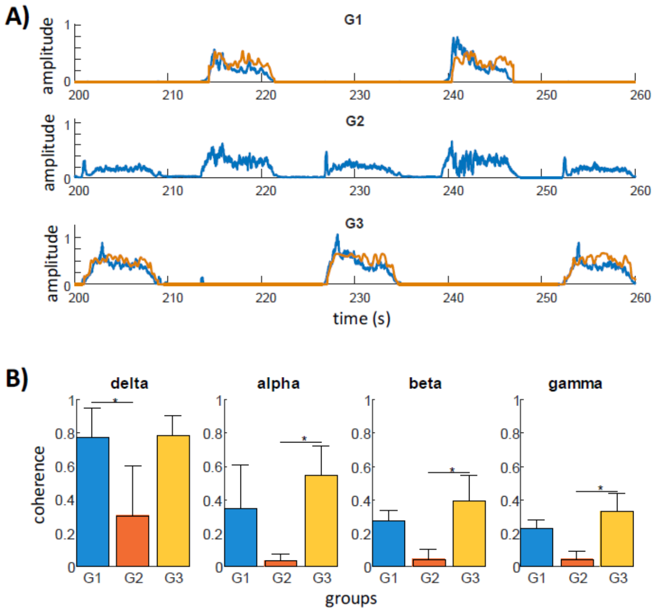

Figure 1: A) Comparison between NMF components (blue) and cumulative MU spike trains (orange) in different groups of sources. For clarity reasons, only 60 s out of 260 s long contractions are depicted. B) Maximal coherences between NMF components and cumulative MU spike trains in different source groups and different frequency bands; * statistically significant difference (Kruskal–Wallis test, $p < 0.05$)

S1.4 Physiology and anatomy of the complete facial musculature assessed from high-density surface EMG

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INTRODUCTION: The facial musculature contributes to many important functions such as speech, food intake and mediation of emotional and affective states. Moreover, there are several neurological diseases with severe affection of the facial musculature. Despite its functional and clinical importance, systematic topographical data on the facial musculature at a single motor unit (MU) level have been lacking. AIM: To topographically characterize the MUs of the upper, midfacial and lower facial muscle subcomponents including the periorbital and lip musculature.

Methods: High-density surface EMG (HDsEMG) was recorded in five separate measurement sessions from 21 individual facial muscle subcomponents using 0.3mm-thin multi-electrode grids with a maximum of 256 channels. In total, thirty-nine healthy adult subjects were trained in performing slight to moderate selective contractions of investigated muscle subcomponents. Multichannel motor unit action potentials (MUAPs) were decomposed by convolution kernel compensation technique as described by Holobar and Zazula in 2007. For each MUAP, the initiation and propagation of the potential were topographically identified in the time sequence of the interpolated monopolar amplitude maps to determine motor endplate zones and muscle fiber directions.

Results: Generally, our findings confirm previous anatomic studies demonstrating high inter-individual variability in the anatomy of the facial musculature with absence of certain muscle subcomponents in some individuals and varying fiber architecture and innervation zone locations. Decomposed MUAPs reveal the distinctive topographical characteristics of facial MUs, such as overlapping territories of MUs belonging to different muscles and the occurrence of asymmetrically located endplate zones within single muscles. In the upper facial muscles as well as the orbicularis oculi we found widely distributed motor endplate locations over the muscle. In the other subcomponents, clustering of endplate zone locations has been found at least to a certain extent with more or less varying locations of endplate clusters between individuals.

Conclusions: Results of this series of studies are unique with regard to the fact that topographical information has been obtained at the level of the smallest functional neuromuscular units (i.e., the MUs) from a relatively large group of healthy individuals without dissection of human cadavers. This allows the use of the individual results for optimizing functional investigations, e.g. establishing electrode placement guidelines for speech and psychophysiologic research, and for endplate-targeted Botulinum neurotoxin injection with reduced side-effects. Beyond this practical and clinical relevance, the systematic topographical data on the architecture of the whole facial muscle system adds substantially to the sparse neurophysiological and anatomical knowledge at the level of the smallest functional units.

S1.5 The role of HD-EMG in Cerebral Palsy: Implications for research and clinical practice

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BACKGROUND AND AIM: Cerebral Palsy (CP) is one of the main causes of physical disability with a prevalence of 1.5-3 cases per 1000 newborns [1]. It has highly individual manifestations, providing difficulties for its classification and categorization. For instance, frequent clinical manifestations of CP include the loss of selective motor control, spasticity, hypertonia, muscle weakness and incoordination. However, the common use of subjective assessment scales in clinical practice - e.g. the Modified Ashworth Scale and Modified Tardieu Scale - might lead to treatment strategies that depend on the clinician's experience [1, 2]. While CP is a lifelong condition with no cure available to date, secondary musculoskeletal problems progress over time. Hence, CP management primarily focuses on re-establishing or maintaining motor capabilities as well as pain management and prevention of contractures [1]. Until now, the reasons for progressive neuromuscular changes in CP are still not entirely understood. Recent efforts are made towards more objective and quantitative examination of motor abnormalities using gait analysis and imaging methods, such as ultrasonography and MRI [1].
Methods: In this context, non-invasive HD-EMG presents a promising tool to provide more insights into CP. The decomposition of HD-EMG signals allows for a better characterization of muscle control patterns and has been used in various clinical applications including stroke, diabetes type 2, pathological tremor and cleft-lip patients [3].

Results: The upper motor neuron lesions in CP lead to substantial changes in the neuromuscular activity of motor units. In our preliminary tests with HD-EMG recordings of five CP children (age between 5 and 14 years; GMFCS between II-IV), we reliably identified 5.6 ± 2.4, 4.9 ± 2.1 and 5.4 ± 1.8 motor units per low, moderate and high force isometric contraction of biceps brachii muscle, respectively. The identified motor units exhibited irregular firing patterns with large firing rate variability. The average coefficient of variation for interspike interval ranged from 19 % to 170 % with average values of 60 ± 28 %, 58 ± 38 % and 68 ± 40 % for low, moderate and high contraction levels, respectively.

Conclusions: Our results demonstrate that the noninvasive identification of neural codes for children with CP is feasible. Therefore, this methodology can be used to assess neuromuscular adaptations to the upper motor neuron lesions and to track the secondary musculoskeletal problems over longer periods. A better understanding of neural mechanisms that lead to morphological, functional and mechanical changes of muscle properties could potentially improve the clinical reasoning for treatment strategies to optimize the outcome, and foremost life quality, for individuals with CP.

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S1.6 Aging, lifestyle-related disease, exercise, nutrition, and motor unit firing pattern in humans - Challenges to resolve Japanese social issue using HDsEMG

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Chukyo University

The life expectancy of Japanese is increasing and has been among the highest in the world for a long time. On the other hand, the total increase of life expectancy (1.91 ys) was greater than that of healthy life expectancy (1.67 ys) from 2001 to 2013, meaning that the period of life necessitating nursing care is also increasing. To resolve this social issue, countermeasures to tackle age-related physiological dysfunction need to be urgently established in Japan. The foundations of such countermeasures are appropriate levels of physical activity and dietary habits. Although the effects of exercise and dietary interventions on motor performance and the muscular system in the elderly have been investigated, neural system-based adaptations are not fully understood. Our research group aims to clarify the effects of exercise and nutrition on the elderly neural system by employing high-density surface EMG (HDsEMG). We have already conducted a detailed investigation of motor unit firing properties in the elderly (Watanabe, Holobar, Kouzaki, Ogawa, Akima, Moritani, AGE 2016) and those with type 2 diabetes mellitus (Watanabe, Gazzoni, Holobar, Miyamoto, Fukuda, Merletti, Moritani, Muscle Nerve 2013) using the Convolution Kernel Compensation technique (Holobar et al. Clin Neurophysiol 2009). Recently, we investigated the effect of a combination of resistance training and dietary intervention on motor unit firing patterns in the elderly, and revealed that dietary intervention modifies the motor unit adaptation following resistance training (Watanabe, Holobar, Mita, Kouzaki, Ogawa, Akima, Moritani, in preparation). The dietary intervention in this study comprised an addition of fish-based protein to normal meals, since one of the features of the traditional food culture in Japan is high-level fish consumption. In 2013, Japanese traditional dietary culture, Washoku, was added to the UNESCO heritage list, and functional foods related to traditional Japanese food culture are now attracting global interest (Nature 2017). Our novel approach using HDsEMG may help to resolve the Japanese social issue of the superaging of society with the aid of Japan's traditional food culture. This research is supported by the Japanese National Project (Japanese Council for Science, Technology and Innovation (CSTI) and Cross-ministerial Strategic Innovation Promotion Program (SIP Project)).

S2 SYMPOSIUM: MUSCLE STIFFNESS AND EXTENSIBILITY: HOW DO THEY AFFECT MUSCLE FUNCTION?

S2.1 Introduction and Overview of stiffness measurement

Massimiliano Ditroilo
University College Dublin

Skeletal muscle stiffness, the relationship between applied load and elastic deformation, is one of the most investigated mechanical properties in humans. It is an important neuro-mechanical component related to athletic performance and injury risk (Ditroilo et al 2011a). It can be measured from the micro level of a single muscle fibre to the macro level of the entire body (Butler et al., 2003) and this obviously affects the method of assessment. In this symposium two categories of techniques for stiffness measurement will be examined. The first one is based on the ratio between ground reaction force and centre of mass displacement while hopping vertically (McLachlan et al 2006; Hobara et al 2013). However the same principle can be applied when hopping on a specially built sledge apparatus (Comyns et al 2007) or during running (Morin et al 2005). Vertical hopping is a popular test in team and individual weight-bearing sports, mainly because it is easy and quick to administer. Additionally, it can be performed on a force plate but also on a contact/infrared mat. This method, which evaluates vertical stiffness (Kvert), is regarded as a global measure of lower body stiffness and is often calculated as follows (Hobara et al 2014): Kvert = Fpeak/D, where Fpeak is the peak force during contact time and D is displacement of centre of mass at peak force. Although other methods of calculating Kvert exist (Hobara et al 2014). If a contact/infrared mat is used, Kvert can be calculated using flight time, contact time and body mass (Dalleau et al 2004). A second category of techniques to measure stiffness relies on the frequency response of perturbed joints (Kearney and Hunter, 1990). Among them, quite common is the recording of damped oscillations of a perturbed joint which vibrates at its natural frequency. This method has been named free-oscillation technique (Shorten, 1987; Wilson et al., 1994). It has been recognised that it evaluates musculo-articular stiffness (MAS), stiffness of a whole joint which encompasses the stiffness of the muscle-tendon unit, along with skin, ligaments and articular capsule (Ditroilo et al, 2011a). MAS is calculated as follows (Ditroilo et al 2011a): MAS = m·(4π2·f2 γ2), where m is mass of the system under consideration, f is frequency of oscillation and γ is damping coefficient. Interestingly, more recently the free-oscillation technique has been applied to a localised structure, i.e. a single muscle, by applying a perturbation with a dedicated portable device (Bizzini and Mannion, 2003). Even though this technique is based on the frequency response to a mechanical perturbation, it is of note that stiffness is calculated similarly to Kvert, i.e. working out the peak force applied during the perturbation and dividing this value by the displacement of the perturbed tissue (Ditroilo et al 2011b).

S2.2 Muscle stiffness relates to athletic performance and injury risk status

Mark Watsford
University of Technology Sydney

This presentation examines the inter-relationships between stiffness and extensibility in the context of athletic performance and injury incidence. The juxtaposition of performance maximisation whilst being mindful of injury risk will be considered based on available evidence. Given the variety of clinical and functional assessment techniques for different body segments, it appears that stiffness assessment is a valuable tool for practitioners in the quest to understand muscle function. Stiffness, extensibility and flexibility are fundamentally different neuromechanical properties, each of which uniquely contribute to performance and injury risk. It is clear that stiffness is closely related to athletic performance. A range of studies examining the lower-body have stipulated that higher stiffness is synonymous with superior jumping, sprinting, agility and strength performance. Such research originates from sports such as track and field, football, and netball, among others. Many of these components rely primarily upon relatively fast stretch shorten cycle movements and evidence suggests that higher stiffness contributes to faster rate of force development, reduces electromechanical delay and may be linked to higher power output. Higher stiffness may also lead to differing responses under conditions of neuromuscular fatigue, presenting an array of implications for endurance athletes. In contrast, reduced levels of stiffness, and associated greater extensibility, are linked to superior performance in relatively slow stretch shorten cycle activities. However, evidence suggests that the ability to rapidly generate force outweighs the benefits of utilising elastic recoil energy, therefore, the general consensus appears to favour elevated muscle stiffness levels where optimal performance output is sought. Despite the notion that higher stiffness levels are effective for enhancing performance, practitioners must also consider the U-shaped relationship between stiffness and injury risk. Research from football and netball indicates that stiffness magnitude or bilateral asymmetry may contribute to injury incidence. Specifically, stiffness values that are too high or too low may increase the stress on the musculoskeletal system upon landing or loading, elevating injury risk. The absence of knowledge pertaining to optimal stiffness levels leads to uncertainty in terms of exercise prescription, however, evidence suggests that various acute and chronic stimuli can modify stiffness or extensibility. Accordingly, applications for enhancing performance in the absence of elevating injury risk are important. It is clear that strength training, flexibility training or plyometric training influence stiffness, as does altering the landing surface, and we recently examined the effect of training in an aquatic environment to manipulate landing loads. These results, along with proposed mechanisms will be discussed in the presentation.

S2.3 Effects of age, sex and fatigue on musculoskeletal stiffness

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University of Beira Interior

Stiffness is a mechanical property frequently addressed in human studies. In general terms, stiffness is the ratio of force change-to-length change that results from the deformation of an elastic structure when a force acts on it (Butler et al., 2003). This property has been extensively investigated over the last years, with some studies exploring the effects of age, sex and fatigue on stiffness, which will also be the focus of this symposium. Aging has been associated with a progressive loss of muscle strength, muscle mass, and loss of strength per unit muscle mass (Goodpaster et al., 2006). Some research suggest that tendon stiffness is reduced with aging (Mademli and Arampatzis, 2008, Reeves et al., 2003), but other reports have shown greater tendon stiffness (Shadwick, 1990) or no changes (Couppé et al., 2009) with aging. Conflict results have also been presented for MAS, with studies revealing no differences in MAS due to aging (Ochala et al., 2004) and others showing greater MAS in older women (Faria et al., 2011). The current results substantiate some effect of aging on stiffness, nonetheless this effect is not fully understood and needs further development. It is well established that men show greater stiffness than women. This result was found in studies examining sex differences in stiffness of the plantar flexors (Blackburn et al., 2006), knee flexors (Blackburn et al., 2004), knee extensors (Granata et al., 2002b) and in the whole leg (Granata et al., 2002a). Fibre length, pennation angle and muscle thickness can differ across sexes (Chow et al., 2000, Kubo et al., 2003, Mademli and Arampatzis, 2005), affecting stiffness and force production (Mademli and Arampatzis, 2005). Sex differences in stiffness can also relate with hormones (Bell et al., 2012, Granata,Wilson, 2002b). Fatigue influence factors like muscle activation patterns (Avela and Komi, 1998), co-activation (Weir et al., 1998) and rate of force development (Zhou et al., 1996). Joint and lower limb stiffness can also be affected by fatigue, particularly, through some of these factors. A decrease in stiffness due to fatigue was reported for the plantar flexors (Rojhani-Shirazi and Saadat, 2014), quadriceps (Ditroilo et al., 2011), elbow extensors (Zhang and Rymer, 2001), and tendon knee extensors (Kubo et al., 2001). Few research explored the effects of fatigue on stiffness across sexes. Within these studies muscle fatigue stimulated through hopping tasks didn't promote significant changes on vertical stiffness for both sexes (Padua et al., 2006) but a reduction in knee MAS was found for men and women after a cycling fatigue protocol (Wang et al., 2016). When fatigue was generally induced knee MAS was also reported to decrease for both sexes but when locally induced only female's knee MAS increased (Wang et al., 2017).

S2.4 Leg stiffness during hopping with and without biological legs

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BACLGROUND AND AIM: During hopping and jumping, our legs exhibit characteristics similar to those of a spring (Farley and Ferris, 1998). The leg spring is compressed during the first half of the stance phase and rebounds during the second half, first storing and then releasing elastic energy. To quantify the properties of this sequence, the whole body is often modelled utilizing a ‘’spring-mass model’’ which consists of a body mass and a linear spring supporting the body mass (Blickhan, 1989; Farley and Ferris, 1998). Leg stiffness, which is defined as the ratio of maximal ground reaction force to maximum leg compression at the middle of the stance phase, has been shown to correlate with sprint ability in athletes (Bret et al., 2002; Chelly and Denis, 2001; Durand et al., 2010; Hobara et al., 2012). Therefore, an increased understanding of leg stiffness regulation will provide us with a basis for better evaluating changes in stiffness which accompany training regimes and would be expected to aid in the development of more effective training methods during sports activities.

Methods: We compared the leg stiffness during one-legged hopping at around 2.0 Hz among different training groups: power-trained athletes, endurance-trained athletes, able-bodied untrained subjects, and a long jumper with unilateral below-the-knee amputation wearing running-specific prosthesis.

Results: We found that the power-trained athletes demonstrated higher leg stiffness than the distance runners (Hobara et al., 2008). However, the endurance-trained athletes also demonstrated higher leg stiffness than untrained subjects (Hobara et al., 2010). These results suggest that endurance training enhances the leg stiffness, but power training, including weight training and/or plyometrics, has a stronger influence on leg stiffness than endurance training. We also computed leg stiffness in a long jumper with unilateral below-the-knee amputation wearing running-specific prosthesis. It is worthwhile to note that the leg stiffness of the unaffected leg (non-take-off leg) was similar, but that of the affected leg (take-off leg) of a long jumper with unilateral below-the-knee amputation was lower than the leg stiffness of power-trained and endurance-trained athletes. This may be due to the mechanical properties of running-specific prosthesis and/or muscle weakness/impairment of residual limb due to atrophy after amputation that could limit force production capability.

Conclusion: In spite of its simplicity, leg stiffness could be a potential global parameter to evaluate performance and musculoskeletal adaptation in athletes. Although some cross-sectional studies indicate that both power and endurance training enhances leg stiffness, the leg stiffness is also modifiable by using assistive devices. In the symposium, assessment of leg stiffness using hopping test with and without ‘biological leg’ are presented.

O2 REHABILITATION THERAPIES AND TECHNOLOGIES

O2.1 Lower limb EMG activity of chronic stroke patients when using a novel gait-retraining device

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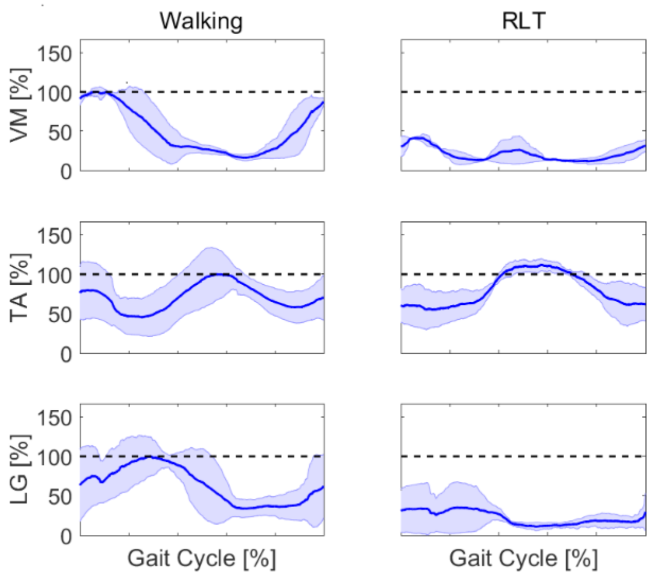
University of Auckland

BACKGROUND AND AIM: The Re-Link Trainer (RLT) is a passive end-effector for gait retraining post-stroke. The device is a modified walking frame with a 4-bar linkage, designed to impose a kinematic constraint on the paretic limb by moving it through a normalized predefined gait path trajectory. Altered lower limb muscle activation post-stroke can influence the quality and functional limitations of the gait pattern. The timing of muscle activation is important for an effective gait pattern post-stoke, therefore it is critical that the RLT creates appropriate lower limb muscle activation patterns in conjunction with the kinematic constraint.

Methods: Five chronic stroke patients (1F/4M; mean ± SD: Height 1.69 ± 0.09m; Weight 79.6 ± 16.5kg; Age 69.4 ± 5.27years; Time since stroke 7.0 ± 3.39years) walked at a self-selected speed over a 7m walkway, followed by walking in the RLT. Unilateral EMG was collected from the paretic limb at 1000Hz using pre-gelled, bipolar Ag/AgCl electrodes from the following muscles: vastus medialis (VM), tibialis anterior (TA) and lateral gastrocnemius (LG). The EMG signal was high- then low-pass filtered with a 4th order Butterworth filter at cut off frequencies of 20Hz and 400Hz respectively, then smoothed by calculating the root-mean-square value for each 100ms sliding window of data. The EMG trace of each muscle was segmented according to the gait cycles. Noisy channels, defined as those where muscle activity could not be visually distinguished from baseline noise, were manually identified and eliminated prior to analysis. The EMG for each lower limb muscle when using the RLT was normalized to the maximum EMG obtained in the overground walking trial for each subject. The difference in maximum amplitude and the shift in maximum amplitude between overground walking and the RLT was examined. Paired sample T-tests were used to assess alterations in the maximum EMG amplitude and shift in maximum EMG amplitude when using the RLT compared to overground walking.

Results: There were large inter-individual differences in EMG activity, and EMG could not be obtained from all participants. The EMG profiles for all muscles across both walking conditions are displayed in Figure 1. EMG could not be obtained for all participants. Compared with normal walking, peak VM activity occurred significantly later when using the RLT ($P=0.014$), however a significant shift was not evident for TA and LG ($P>0.05$). There were no significant alterations in maximum EMG amplitude for any muscle group (LG and VM n=2, TA n=4; $P>0.05$).

Conclusions: An initial hypothesis was that when a limb is constrained by the RLT the user may not activate their muscles to the same extent since they are being assisted to take the step. However, although a visual inspection suggests there are differences, the EMG amplitudes were not significantly reduced in the constrained limb when walking in the RLT.


Walking
RLT
VM [%]
TA [%]
LG [%]
150
100
50
0
Gait Cycle [%]
Gait Cycle [%]

O2.2 Multisite stimulation to reduce fatigue associated with functional electrical stimulation

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University of Arizona, College of Medicine

BACKGROUND AND AIM: Restoration of motor function in paralyzed limbs using functional electrical stimulation (FES) has not gained widespread use due, in part, to rapid fatigue associated with artificial stimulation. Typically, single intramuscular electrodes are used to activate muscles with FES. However, due to the highly distributed branching of intramuscular motor axons, a single electrode may be insufficient to activate the entire nerve array supplying a muscle. Therefore, stimulating with multiple, spatially distributed electrodes might enable access to a larger volume of muscle fibers. This, in turn, should facilitate load- sharing among muscle fibers, reducing fatigue. Accordingly, the aim of this study was to compare fatigue responses associated with contractions elicited by electrical stimulation delivered by a single intramuscular electrode to that involving multiple electrodes.

Methods: Five healthy human subjects each participated in 4 experimental sessions. In each session, the endurance time associated with a sustained ankle dorsiflexion at 20% of the maximum voluntary force was measured. In different sessions, force was evoked in response to feedback-controlled electrical stimulation of the tibialis anterior using a single intramuscular electrode, multiple intramuscular electrodes, or a single intraneural electrode inserted into the peroneal nerve. In addition, in one session, subjects performed a sustained voluntary contraction at the target force. In all sessions involving electrical stimulation, a localized nerve block was applied to the peroneal nerve proximal to the knee in order to alleviate discomfort and activation of reflex pathways associated with strong electrical stimulation. Electrical stimulation (25 Hz) involved feedback control of stimulus pulse amplitude until the evoked force could no longer be maintained within 10% of the target force.

Results: Endurance time was substantially less for that involving single electrode stimulation (77 s) compared to that involving multiple electrodes (225 s), extraneural stimulation (770 s), or voluntary contraction (885 s). Interestingly, in two subjects, endurance time was greater for nerve stimulation than for voluntary contraction.

Conclusions: Therefore, it appears that a marked reduction in FES-related fatigue can be achieved using stimulation strategies that access a greater proportion of the nerve array supplying muscle. Furthermore, these results suggest that FES is not inherently more fatiguing than voluntary contraction.

O2.3 Long-term effects of providing ankle-foot orthoses after stroke on tibialis anterior muscle activation patterns

Corien Nikamp, Jaap Buurke, Leendert Schaake, Johan Rietman, Hermie Hermens
Roessingh Research & Development

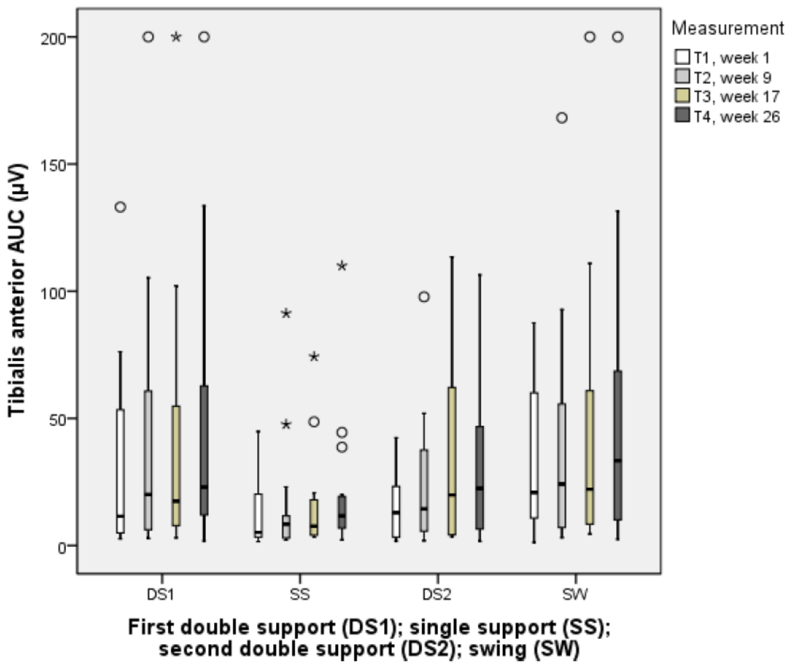
BACKGROUND AND AIM: Ankle-foot orthoses (AFOs) are often used to improve walking after stroke, and are found to improve functional outcome and ankle kinematics. However, some clinicians are reluctant to prescribe AFOs after stroke as they fear AFOs would lead to disuse of the tibialis anterior (TA) muscle, thereby delaying and impeding recovery. Results of studies investigating effects of AFOs on TA-activity are inconclusive, as types of AFO and the specific phase of the gait cycle that is studied, seem to influence conclusions. More important, long-term effects of AFO-use on TA muscle activation patterns after stroke are unknown. Therefore, we studied stroke patients that were provided with an AFO early after stroke. We studied whether AFO-provision affected TA muscle activity over time during walking without AFO.

METHODS: As part of a larger randomized controlled trial on the effects of AFO-provision in (sub-)acute stroke (≤6 weeks), unilateral ischemic or hemorrhagic stroke subjects with AFO-indication were provided with an AFO directly after inclusion. Surface electromyography of the TA was measured four times: in week 1 (T1), 9 (T2), 17 (T3) and 26 (T4) of the study. Subjects were measured at self-selected walking speed. In case subjects were not able to walk independently (FAC-level≥3), the measurement was postponed. For analysis, the gait cycle was split into four sub-phases: first double support (DS1), single support (SS), second double support (DS2) and swing phase (SW), using initial contact and toe-off of both sides. Each sub-phase was time-normalized to 100% and the average Area Under the Curve (AUC) was calculated to express the activity level. Data were LN-transformed before mixed model analysis was performed and walking speed was included as a confounder.

RESULTS: Fifteen subjects were included, on average 29.1 (6.5) days after stroke. One subject was unable to perform the first measurement and one subject missed the third measurement. On average, measurements were performed 51.2 (16.1), 90.1 (6.5), 146.8 (7.3) and 209.4 (7.4) days after stroke. Figure 1 shows box-plots of the AUC of the TA per sub-phase over time. Mixed model analysis of the LN-transformed data showed no changes over time in AUC-values in any of the sub-phases (p=0.92; 0.53; 0.62 and 0.42 for DS1, SS, DS2 and SW, respectively).

CONCLUSIONS: We found that muscle activity of the TA, expressed as AUC per sub-phase, did not change over a period of six months in (sub-)acute stroke patients who were provided with an AFO. In case of disuse, one would expect the AUC to decrease over time. In our population, we did not found any indications that the AUC decreased. Therefore, we have no reasons to believe that AFO-use early after stroke leads to disuse of the TA when walking without AFO is measured over a period of six months. Whether not providing an AFO would lead to increased AUC-levels remains unclear and is a topic for future study.

Figure 1. Boxplots of AUC of tibialis anterior without AFO over time, displayed per sub-phase.



Note: for better visual interpretation outliers >200µV were presented at 200 µV

O2.4 The effect of long-term treatment with transcranial pulsed electromagnetic fields on sit-to-stand performance in persons with Parkinson's disease.

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BACKGROUND AND AIM: Parkinson's disease (PD) is associated with severe motor deficits as the disease progresses. Among the deficits are slow movements and decreased functional rate of force development [1]. Exposure of neuronal tissue to pulsed electromagnetic fields have neuro-repair effects and may increase excitatory neurotransmission when applied transcranial in humans (T-PEMF) [2]. Thus, T-PEMF may potentially reduce neurodegeneration in PD and facilitate movement. Our aim was to study the effect of long-term treatment (3x8 weeks) with T-PEMF on movement speed and functional rate of ground reaction force development (RFD) during chair rise.

Methods: Twelve persons with PD (age 67±2 years, 3 women, UPDRSIII 27.6±4.4) received one daily home-based session of 30 min T-PEMF (squared bipolar pulses of 3 ms duration, 5 mT, 55 Hz [1]; Re5, Denmark) for 3x8 weeks separated by 1 week of pause. Pulses were given through seven circular coils located bilaterally in the anterior-temporal, posterior-temporal, and frontal-parietal region along with one in the central occipital region. Six persons with PD not receiving T-PEMF participated as controls (CON) (age 71±2 years, 1 woman, UPDRSIII 22.6±1.7). Six-cycle sit-to-stand test was performed as fast as possible on a force plate before (W0), after 2x8 (W18) and 3x8 (W27) weeks of T-PEMF treatment. The completion time of five sit-to-stand repetitions and mean RFD during rising was determined [3].

Results: There was a significant time*group interaction on completion time ($p = 0.003$). The T-PEMF group significantly reduced their completion time by 20 % from W0 (10.3± 0.6 s) to W27 (8.3± 0.5 s, week 0-27 $p < 0.001$), whereas CON did not change (W0 = 9.6±0.9 s, W27 = 9.9± 0.7 s, $p = 0.50$). The T-PEMF group increased the RFD by 8% from W0 (9.8±0.7 xBW/s) to W27 (10.5±0.7 xBW/s, $p = 0.047$). CON did not change (W0 = 10.4±1.0 xBW/s, W27 = 10.6±1.1 xBW/s, $p = 0.49$). However, no significant group*time interaction was found in RFD ($p=0.62$).
Conclusion: 3x8 weeks of treatment with T-PEMF reduced completion time and increased RFD during a six-cycle sit-to-stand test in persons with PD. Agonist drive is impaired and co-contraction increased in PD [4]. Thus, the observed improvements may be due to increased agonist drive and/or reduced co-contraction resulting in increased rate of net joint torques in knee and hip particularly. The results suggest that treatment with T-PEMF has the potential to improve motor function in PD.

AKNOWLEDGEMENTS: We thank the A. P. Møllerske Støttefond, Jascha Foundation and Grosserer LF Foghts Foundation for financial support.

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O2.5 Effects of transcutaneous electrical spinal cord stimulation on spinal excitability in individuals with incomplete spinal cord injury

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BACKGROUND AND AIM: Gait dysfunction is a common consequence after incomplete spinal cord injury (iSCI) and frequently persists even following rehabilitation. Recently, transcutaneous electrical spinal cord stimulation (tSCS) has been reported to improve ambulation in iSCI individuals and was proposed as a potential therapy assisting approach in locomotor rehabilitation after iSCI. This technique is suggested to stimulate afferent fibers entering the spinal cord through the dorsal roots and thereby enhancing the excitability of spinal neuronal circuits. However, mechanisms underlying the effects of tSCS have not yet been investigated in detail. Mechanisms of tSCS can be investigated using polysynaptic spinal reflexes (SRs) since they reflect spinal excitability and involve interneuronal circuits associated with locomotion. While SRs are dominated by an early response in healthy individuals, SRs change over time after an iSCI and a late response dominates in chronic patients with reduced locomotor capacity. Additionally, it has been shown that the early response usually dominates in ambulatory iSCI individuals and it can be facilitated by locomotor training. Therefore, SRs activity has been suggested as a marker for locomotor capacity.

Methods: In this study, SRs were elicited by electrical tibial nerve stimulation in 8 chronic iSCI individuals. The reflex response was characterized with the EMG signal of the ipsilateral tibialis anterior muscle. SRs were assessed two times with the same stimulation intensity (1.5x reflex threshold); first before and then during tonic tSCS. The tSCS was applied with one electrode placed on the spinous processes of the T11 and T12 vertebrae and two larger electrodes placed on the lower anterior abdomen in symmetry to the umbilicus. The tonic stimulation consisted of rectangular biphasic pulses with a pulse width of 1 ms delivered continuously at a frequency of 30 Hz.

Results: During tSCS a facilitation of the early reflex response was observed and occasionally accompanied by a decrease of the amplitude of the late response.

Conclusion: These findings suggest that tSCS interacts with spinal neuronal networks and possibly increases their excitability. As SR activity was suggested as a marker for ambulatory capacity, these findings further support a possible application of this technique in locomotor rehabilitation. Effects of repeated long-term administration of tSCS in combination with ambulatory training still have to be investigated to gain further insights into the possible benefits of tSCS. Moreover, it will be of interest to investigate whether tSCS applied in subacute iSCI individuals is able to diminish maladaptive changes within spinal locomotor networks and consequently enhance ambulatory rehabilitation already at an early stage of recovery.

O2.6 Time course of the effects of botulinum toxin on voluntary activation and on reflex responses of spastic motoneurons in biceps brachii muscles based on surface EMG recordings

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BACKGROUND AND AIM: Botulinum toxin (BT) is widely used in clinics to reduce muscle spasticity in chronic stroke. After muscle injection, BT acts to denervate muscle fibers and thereby reduces unwarranted muscle contraction. Animal studies have shown that denervation of both alpha and gamma motoneurons occurs. Still, the time course and distribution of the effects of BT on extrafusal vs. intrafusal muscle fibers is not well documented in human. Here, we report the time course of the effects of BT injected in the Biceps Brachii's (BB) of a stroke survivor during voluntary activity (extrafusal) as well as in stretch responses (intrafusal) using a grid of surface EMG (sEMG) electrodes.

Methods: We recorded 128 monopolar sEMG channels using a 16x8 grid with 8mm interelectrode distance. The subject was seated in a Biodex chair with joint angles preset. Grid electrodes covered long and short heads of BB. A 6 DOF load cell was used to record Forces/torques in sync with sEMG. Voluntary sEMG data was recorded during a sustained isometric non-fatiguing elbow flexion for maximum voluntary contraction (MVC), 30%MVC and 50%MVC. Stretch reflex responses were collected using a tendon tap hammer, equipped with a force sensor at its tip to measure the applied tapping forces. We recorded evoked EMG potentials using repeated tappings (4s apart) of the bicipital tendon, with a wide range of impact force amplitude (1 to 40 N) applied randomly. We collected data before injection and post-injection for up to 18 weeks biweekly. The pre-BT data was used as a baseline reference for analytical comparison with post BT data. The sEMG and the Force data were used for analysis after offset removal, zero-lag bandpass filtering (10-500Hz). The root-mean-square (RMS) maps over the steady state force period (3s-8s) were computed in order to characterize the spatial pattern of voluntary activities. For the reflex responses, the RMS map of each tendon tap (TT) over 50ms of the evoked potential was analyzed. For each electrode, we obtained an RMS amplitude versus TT force curve. Then we overlaid the curves from all recording sessions to analyze the time course effect of the neuro-toxin injection on BBs' intrafusal fibers.

Results: The RMS voluntary maps clearly show a significant drop in muscle activity 2 weeks after the BT injection. Subsequently, partial recovery of muscle activity was non-uniform, faster in proximal-distal direction than medial-lateral, recovering to baseline beginning at 4 weeks and fully after 6 weeks post-injection. For the reflex responses, the significant decrease in evoked potentials occurred 4 weeks post-BT and lasted up to 18 weeks.

Conclusions: We report evidence for a differential effect on voluntary and reflex activity after BT injection, which implies a time difference in the recovery of alpha MN and gamma MN innervation to extrafusal and intrafusal fibers. We are recruiting more subjects to study the BT effect in a larger stroke population.

O3 MOTOR CONTROL I - MUSCLE SYNERGIES

O3.1 Muscle synergy extraction using principal activations only: is this information more useful in clinics and robotic control with respect to a classical muscle synergy analysis?

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Politecnico di Torino

BACKGROUND AND AIM: In recent years, the study of motor control was approached by the application of data reduction techniques such as Non-Negative Matrix Factorization (NNMF). Starting from a dataset containing a high number of electromyography (EMG) channel recordings (from 8 to 25 muscles are typically analyzed) the original EMG data matrix is reduced into a vector of time-invariant weights and time-varying coefficients, called muscle synergies. In clinics and myoelectric control of robotic prostheses it is particularly important to obtain a reliable and repeatable extraction of muscle synergies. The aim of this contribution is to introduce a potentially important pre-processing step before muscle synergies extraction is performed: the selection of principal EMG activations and discarding of secondary activations. We hypothesize that using principal activation only may provide more consistent muscle synergies.

Methods: Twelve young healthy subjects walked overground at self-selected pace, for 5 minutes, while EMG signals from 12 muscles of the right lower limb and trunk were recorded. The principal activations were determined using the CIMAP clustering algorithm [1]. The extraction of muscle synergies with NNMF was performed: (1) using only the EMG principal activations (novel approach); (2) using the whole EMG signals (traditional approach). The within-subject consistency of muscle synergies during the gait trial was calculated in both cases using cosine similarity (CS) for the weights and zero-lag cross-correlation (CC) for the time coefficients, as similarity measures [2].

Results: We found more consistent muscle synergies when principal activations only were used to process EMG signals. In fact, both CC and CS were significantly higher in the novel approach with respect to the traditional one (CC = 0.98 ± 0.03 vs. 0.93 ± 0.06, p = 0.007; CS = 0.99 ± 0.01 vs. 0.96 ± 0.03, p = 0.002).

Conclusion: We demonstrated that keeping principal activations only, while discarding secondary ones, is an important pre-processing step to be performed before muscle synergy extraction to obtain more consistent results. This novel approach may be especially relevant in clinics and in the myoelectric control of prostheses where a high consistency is a stringent requirement.

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O3.2 Changes in the timing but not the structure of muscle synergies are associated with changes in gait after treatment in cerebral palsy.

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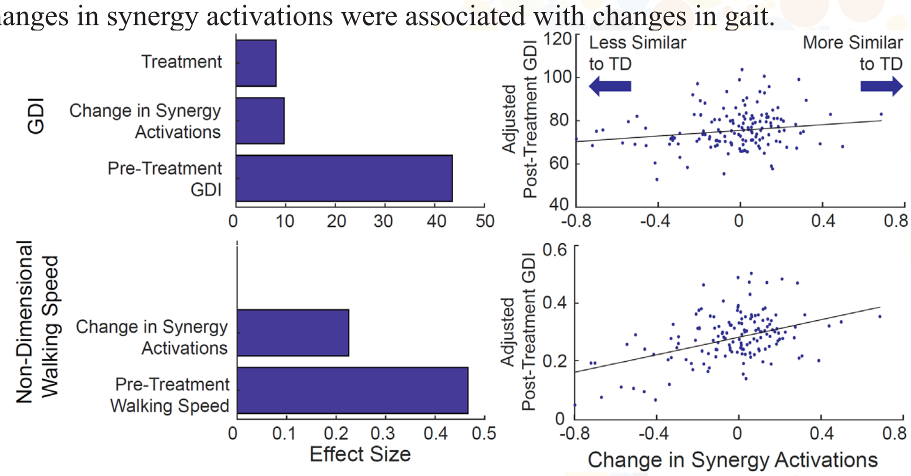
Background and Aim: Cerebral palsy (CP) is a neuromuscular disorder caused by an injury to the brain which occurs at or near the time of birth. Each individual with CP has a unique set of impairments, impacting mobility and muscle control. Current treatments include physical therapy, pharmacological interventions such as botulinum toxin injections (BTA), and surgical options such as selective dorsal rhizotomy (SDR) and single-event multilevel orthopaedic surgery (SEMLS). Muscle synergies as a measure of muscle control have been proposed as a tool for treatment planning [1], but it is unclear how synergies may change following treatment, and whether changes in synergies are related to treatment outcomes.

Methods: We retrospectively analyzed gait analysis data with electromyography (EMG) from eight muscles from two groups: 147 children with CP (before and after treatment) and 31 typically developing children (TD). We explored the impact of three common treatments: BTA (n=52), SDR (n=38), and SEMLS (n=57). Synergies were calculated from EMG data using weighted non-negative matrix factorization. The four synergy solution was calculated for each individual and compared to the average TD synergies for weights (cosine correlation) and activations (Pearson correlation). Changes in synergies were evaluated as the average change in correlations across the four synergies pre- to post-treatment. Positive changes indicate patterns closer to TD. Changes in gait were evaluated with the Gait Deviation Index (GDI) and dimensionless walking speed. Stepwise multiple linear regressions were performed for post-treatment GDI/speed with pre-treatment GDI/speed, treatment, age, and changes in synergy weights or activations as possible explanatory variables.

Results: Relative to TD, there were small changes in synergy weights and activations after treatment (change < 0.1 and 0.2 for 73% and 74% of individuals for weights and activations, respectively). After controlling for pre-treatment values, changes in synergy activations were significantly associated with post-treatment GDI ($p<0.049$) and speed ($p<0.001$, Figure 1), where activations more similar to TD after treatment were more likely to have positive improvements in GDI and speed. Changes in synergy weights were not associated with changes in gait.
Conclusions: Synergy activations that more closely resembled TD activations after treatment were associated with better gait outcomes. These findings suggest that, while these treatments may not adjust synergy weights, targeting the timing of synergies may improve treatment outcomes. References: [1] Schwartz 2016 DMCN. Figure 1: Effect sizes of regression models (Left) and adjusted responses (after controlling for pre-treatment GDI/walking speed) of changes in the correlation coefficient between an individual's synergy activation curves and the mean TD activations (Right). For GDI and walking speed, changes in synergy activations were associated with changes in gait.



O3.3 Divergence in temporal coordination of kinematic synergies during non-preferred stride time-length combinations

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Kyoto university

BACKGROUND AND AIM: Although we appropriately coordinate whole body movements during walking, whole body kinematic coordination may disrupt when we select non-preferred stride time-length combinations. In order to quantify whole body kinematic coordination, the groups of simultaneously active segments (intersegmental coordination) and their activation patterns (temporal coordination) have been investigated as the kinematic synergies. To estimate fall-risks of walking, it has been examined that divergence of kinematic data during walking based on the maximum Lyapunov exponent. The previous research revealed that high maximum Lyapunov exponents in kinematic data related to fall-risks. Therefore, the maximum Lyapunov exponents would reflect collapse risk of walking motion. Then, we investigated the maximum Lyapunov exponents in temporal coordination of kinematic synergies during various stride time-length combinations. The purpose of this study was identifying divergence of whole body kinematic coordination during non-preferred stride time-length combinations.

Methods: Ten healthy men (age: 25±2.6 years, height: 171.2±2.23 cm) walked on the treadmill over 160 gait cycles. Subjects walked at 3 non-dimensional walking speeds (0.15, 0.4 and 0.7) by 5 types of stride length (very short, short, preferred, wide and very wide). During walking, visual feedback on current stride time-length combinations were given by the Labview to adjust desired stride time-length combinations. We recorded 3-dimensional marker position data in whole body. The kinematic synergies were extracted from elevation angle of trunk, thigh and foot segments by the singular vale decomposition. For the calculation of maximum Lyapunov exponents, seven dimensional time delayed coordinate systems were constructed. A positive maximum Lyapunov exponent means that an analyzed data diverges if time delays are given.

Results: We extracted 4 kinematic synergies at each condition and subject. The maximum Lyapunov exponents were high during non-preferred stride time-length combinations (Fig. 1: preferred lines were indicated as black dashed lines). This result indicates that the divergence of kinematic coordination was extremely high during non-preferred stride time-length combinations. Moreover, the area of small maximum Lyapunov exponents were wide in slow walking speed. In addition to that, the area of small maximum Lyapunov exponents were narrow as the walking speed increased. Because the kinematic coordination was hard to diverge during slow walking speeds, the slow walking may be advantageous for elderly adults or persons with disorders.

Conclusion: We revealed that the maximum Lyapunov exponents in temporal coordination of kinematic synergies were high during non-preferred stride time-length combinations. We concluded that collapse risk of whole body kinematic coordination was high during non-preferred stride time-length combinations.

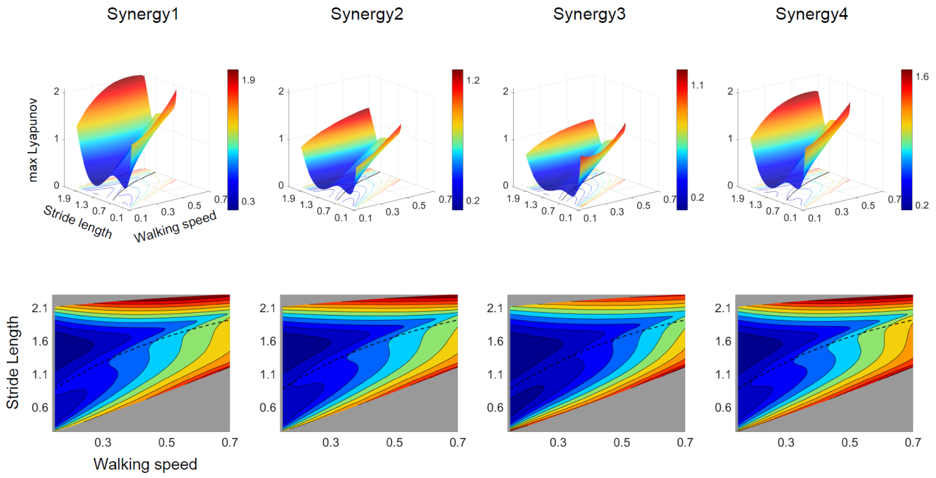
Synergy1
Synergy2
Synergy3
Synergy4
max Lyapunov
Stride length
Walking speed
Stride Length
Walking speed

Figure 1

O3.4 The generalization of Motor Adaptation is explained through the recruitment of previously adapted muscle synergies

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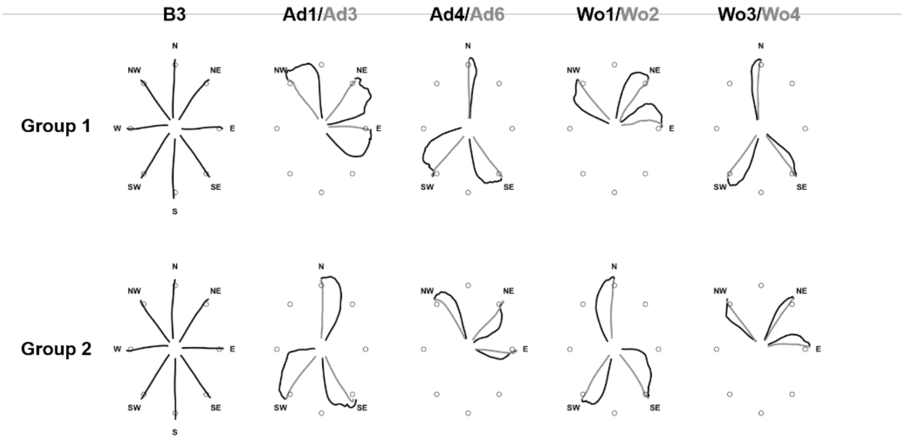
INTRODUCTION: Humans can adapt their motor plan to visual and haptic perturbations, initially producing large errors and then compensating to reduce it, in a process called Motor Adaptation (MA). The CNS is also able to generalize to unlearnt environments the MA plan learned in a different, but similar, environment. This process is generally referred to as generalization. MA and generalization rely on internal models of the body and of the environment to predict the sensory consequences of motor commands. It has been hypothesized that muscle synergies compose the building blocks upon which the CNS builds internal models. In this work we tested if the generalization phenomenon can be explained by the adaptation of specific muscle syneriges.

Methods: 14 subjects performed an isometric reaching task along 8 directions on a plane (Fig.1). The task consisted of isometric hand force (15 N) application on a load cell, while visual feedback was provided. The experimental protocol started with a baseline (BL1-BL3) condition during which the subjects reached 15 times each target in a random order. Then a visuomotor rotation (clockwise 45° rotation of the visual feedback trajectory) was applied. Subjects were divided in two groups (G1 and G2). G1 performed 3 adaptation blocks (Ad1-Ad3) reaching the rotated NW-NE-E targets, followed by 3 generalization blocks reaching the rotated N-SE-SW targets (Ad4-Ad6). G2 followed an inverted target order. Each block consisted of 10 reachings of each target in a random order. EMGs were recorded from 13 upper limb muscles. Muscle synergies (n = 4, VAF > 90%) were extracted from the envelopes of the BL1-BL3 tasks. The extracted syergies were then used to estimate the synergies activation patterns better reconstructing the EMG during the adaptation blocks (VAF > 85%).

Results: During the adaptations blocks (Fig.1), large errors were produced at Ad1, while a complete adaptation to the 3 targets was reached at Ad3. G1 at Ad4 produced large errors towards targets SE and SW, but showed to be already mostly adapted to target N. G2 at Ad4 produced large errors towards target NE, but was already mostly adapted to targets NW and E. Both groups reached a complete adaptation to all targets at Ad6. We found that the reduced kinematic error was systematically linked to a synergy recruitment that matched the one shown to reach the corresponding clockwise rotated target at baseline.

Conclusions: There is at least one target, for both groups, already mostly adapted during the first generalization trial. From a neural control point of view, such target is reached in the rotated domain through the recruitment of synergies that have been previously recruited to adapt other targets. This suggests that MA is achieved through the adaptation of the specific muscle synergies constituting the internal models of the adapted movement and that adaptation is generalized to internal models mapping different movements sharing the same synergies.


B3
Ad1/Ad3
Ad4/Ad6
Wo1/Wo2
Wo3/Wo4
Group 1
Group 2
N
NE
E
SE
S
SW
W
NW

O3.5 Lower-extremities motor adaptations during asymmetric cycling

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BACKGROUND AND AIM: Lower Extremities Motor adaptations (LE-MA) have been widely studied during walking, using both haptic perturbations induced by robots or implicit changes in the kinematics of the task, such as in the split-belt treadmill paradigm. LE-MA have been shown to be driven by stability, symmetry and the minimization of energy consumption, yet it is still not completely clear how this high-level processes combine and how CPGs, cortical commands and reflexes interact during adaptation. Here we tested for the presence of LE-MA during asymmetric static cycling. This condition allows for the elimination of the stability-driven component of adaptation.

Methods: 13 healthy subjects were asked to perform cycling on a modified static cycloergometer, where the angle between the crank arms was altered by 10°. During the experiments data from 2 accelerometers placed on the crank arms and 16 EMG sensors were collected. Participants performed 5 minutes of normal cycling (baseline phase), followed by 10 minutes of asymmetric cycling (adaptation phase) and a final interval of 5 minutes of normal cycling (after-effect phase). All the tests were performed at a fixed speed and power (75rpm, 50W). The data from accelerometers and EMG were compared between baseline and adaptation phase to check for exponential-like changes in the kinematics and in the muscular activity. Non-negative Matrix Factorisation was used to estimate the co-activation patterns and weights of muscle synergies. Five muscle synergies were extracted for each leg in averaged bouts of 10 cycles.

Results: We observed an effect of the asymmetric cycling were subjects adapted their pattern of acceleration exponentially. We observed, in fact, a significant change ($p<0.05$) of the acceleration pattern between baseline and adaptation phase. This kinematic change was mirrored by a bilateral change in shape of activation patterns of the muscle synergies. These alterations are a mix of step-like and exponential modifications. However, no significant changes in involvement of the main muscles within the synergies was found, indicating that the initial modular structure of muscular control was preserved.

Conclusions: The results demonstrate change of acceleration pattern under influence of symmetry based perturbation. The adaptation in the kinematics of movement is connected to bilateral alteration of synergies activation patterns, which adapt similarly. The patterns of adaptation that we observe suggest a regulation of the timing of the CPGs between both sides as main driver of adaptation. Exponential responses indicate a modification in descending cortical commands, which demonstrate that it is possible to shape the corticospinal drive to the different muscles by introducing small asymmetries between the two pedals.

O4 KNEE BIOMECHANICS AND REHABILITATION I

O4.1 Shape analysis of inter-joint motion coupling patterns in a stair-descent task following ACL reconstruction captures asymmetries in coordination up to two years post-surgery relative to non-injured controls

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BACKGROUND: This study focused on the functional coupling between lower-limb joints during a stair-descent task after anterior cruciate ligament (ACL) repair. Surgery may improve knee stability although motor control mediated by sensory feedback (e.g., proprioceptive) may remain impaired. It is not clear if, when and how normal knee function is restored, and whether restoration can be attributed to compensations in other joints rather than to recovery. We assumed that lower-limb control involves coordination and studied spatiotemporal patterns within and between joints. We hypothesized that global patterns of spatial symmetry among the injured and non-injured legs would be an expression of impaired joint coordination post-surgery that would improve given enough time. We also hypothesized that global temporal features would remain invariant (isochrony principle) but the intrinsic temporal structure in the stair-descent would change.

Methods: Data were obtained from 3D marker data recordings (12 stair-descent trials, 6 per leg) to capture alterations in joint kinematics following knee surgery. Inter-joint coupling was determined in unilateral ACL-injured persons (N=32) who underwent reconstruction and were tested either at >1 (Early; N=11), >10 (Mid-term; N=11) and >29mo up to 129mo post-surgery (Late; N=10). Subgroups were compared with each other and with healthy-knee Controls (N=24). Symmetry among legs was estimated using a dissimilarity index (DI) derived from Generalized Procrustes Analyses applied on superimposed average shapes of bilateral two-joints (knee-hip and knee-ankle) and three-joint (hip-knee-ankle) angular displacement-time plots (sagittal plane). One-way ANOVAs and t-tests were used to compare ‘Subgroups’ and ‘Legs’ in terms of kinematic features ($p<0.05$).

Results: ANOVA showed a significant effect of subgroup when using DI. The evidence suggests that asymmetric patterns of joint coupling remain up to ~2ys post-surgery, and that both legs approach similar patterns at longer times ($p=0.0018$). ‘Early’ and ‘Mid’ subgroups were not different from each other but both differed significantly from ‘Late’ and ‘Controls’ ($p<0.01$), which did not differ. Such effects remained undetected using intrinsic measures (e.g., the angular range of joint motion at different stages of the stair descent). Contrary to global spatial measures, global temporal measures were similar among subgroups (e.g., no differences in stance duration) while some measures within the stages of the stair descent changed (e.g., first double-support time).

Conclusions: Up to 10mo from ACL repair, compensation dominates function. Later in the recovery process (>2ys), joint coupling in both legs may share a common kinematic signature (i.e., symmetry) suggesting full recovery. Our results challenge too early return to sports. Further attention to between- and within-leg joint coupling, up to several years following ACL-injury, is warranted.

O4.2 Regional activation of the vastus medialis and lateralis in a dynamic task differs between females with and without patellofemoral pain and is associated with knee extension strength

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BACKGROUND AND AIMS: Altered vasti activation in patellofemoral pain (PFP) has been reported is some, but not all, studies. A possible reason for this discrepancy in findings could be due to muscle activation being recorded from a single location for each vastus, without considering regional activation patterns. In addition, lower knee extension strength (KES) is known to be a risk factor for, and associated with, PFP, but its relation to altered vasti activation patterns is unknown. The aim of this study was to examine whether vasti regional activation patterns differ between females with and without PFP and, secondarily, if muscle activation patterns are associated with KES.

Methods: Thirty-six females with PFP and 20 female controls performed 10 low-force knee flexion-extension movements from 90 to 10 degrees of knee flexion (0 being full knee extension). Activation of vastus medialis (VM) and lateralis (VL) was collected using two high-density surface electromyography grids of 64 electrodes each (13x5, one missing corner). After filtering, the envelopes of the monopolar signals were extracted. Regional vasti coordination was analyzed using Principal Component Analysis, performed separately on the PFP and the control groups. The spatial weights of the principal components (PC)s were compared between groups. The PC temporal coefficients and the variance explained were compared between groups, and between the concentric and eccentric phases of the movement. Correlation analyses were employed to determine the association between features of the PCs and KES.

Results: The spatial weights of PC1 (overall activation) and PC2 (distribution of activity between VM and VL) were similar between groups ($R>0.95$). A lower number of components was necessary to reconstruct 90% of the signal for participants with PFP compared to controls in the concentric phase of the movement ($p<0.05$). Compared to controls, participants with PFP demonstrated less redistribution of activation between VM and VL between the concentric and eccentric phase of the movement ($p<0.05$). This redistribution was inversely correlated with maximal knee extension strength ($R<-0.39$, $p<0.05$).

Conclusions: Our study confirms that vasti activation patterns differ between females with and without PFP. The lower number of PCs necessary to reconstruct the signal and less redistribution of activation between the concentric and eccentric phase of the movement suggest that PFP is associated with a simpler control strategy of the quadriceps. The inverse association between VM/VL redistribution and maximal knee extension strength suggests that there are different presentations of PFP: lower knee extension strength and VM/VL redistribution comparable to controls, or knee extension strength comparable to controls and lower VM/VL redistribution. Future studies are needed to investigate whether different interventions are effective in improving clinical outcomes in females with different PFP presentations.

O4.3 Participants with patellofemoral pain show reduced torque steadiness and higher motor unit discharge rate variability of their knee extensors during open and closed kinetic chain exercises

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Background and aim: Closed kinetic chain (CKC) exercises are recommended as part of the management of patellofemoral pain (PFP), since it has been suggested that CKC preferentially activates the vastus medialis (VM) muscle. However, this observation is not consistent across all studies, possibly due to the limitations of conventional electromyographic (EMG) methods. Here, we aimed to assess muscle activation and motor unit behaviour during open (OKC) and CKC exercises in participants with PFP and asymptomatic control subjects (CONT) using high-density surface electromyography (HDEMG).

Methods: Nine CONT (7 men, age: 27±4 yrs) and nine participants with PFP (6 men, are: 23±5 yrs, KUJALA Anterior Knee Pain Scale score: 82±8/100), performed isometric contractions at 10, 30, 50, 70% of the maximum voluntary contraction torque (MVC), during OKC and CKC knee extension exercises. HDEMG signals were recorded with grids of 13x5 electrodes from the VM, vastus lateralis (VL) and rectus femoris (RF) muscles. The coefficient of variation of torque (CoV torque) was used to quantify torque steadiness during the submaximal contractions. The average rectified value (ARV) averaged across the entire grid and the centroid of muscle activation extracted from the ARV map was obtained from the interference EMG. Multi-channel EMG signals were decomposed into single motor unit action potentials and the corresponding motor unit recruitment threshold, discharge rate and coefficient of variation of the interspike interval (CoVisi) were estimated. Torque data was analysed with two-way repeated measures analysis of variance (ANOVA) (factors: group and exercise), while HDEMG and motor unit data were analysed with four-way repeated measures ANOVA (factors: group, exercise, torque and muscle); $\alpha=0.05$.

Results: CKC exercise resulted in higher peak torques than OKC for both groups ($p<0.0001$), however, there were no differences in peak torque between CONT and PFP participants ($p=0.099$). Despite this, torque steadiness was significantly lower for the PFP group during OKC exercise ($p=0.034$). The average activity of VM, VL and RF didn't differ between groups for both exercises ($p=0.22$). The centroid of activity as also consistent between groups and between exercises ($p=0.46$). Both motor unit recruitment threshold and discharge rate were not different between groups or between the exercises ($p=0.32$ and $p=0.69$), however, the PFP group showed significantly higher CoVisi than CONT during both exercises ($p<0.001$).

Conclusion: Despite previous reports of the advantages of CKC over OKC exercises, we did not observe notable differences in muscle activation across exercises between groups. This was confirmed by the motor unit data since the discharge rates remained consistent regardless of the group (CONT or PFP) or exercise. The decreased torque steadiness in conjunction with higher motor unit discharge rate variability observed for the PFP group, suggests that PFP is associated with a reduced ability to control muscle torque, most notably during OKC tasks. These results suggest that the rehabilitation of people with PFP should aim to improve control of exerted knee force/torque during both OKC and CKC exercises rather than focusing on facilitation of a specific muscle (e.g. higher activation of VM).

O4.4 Reflex changes in ACL deficient knees during normal and surprise landings

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Background: Landings from a jump are often problematic for individuals with anterior cruciate ligament deficiency (ACLD), inducing giving way episodes at the knee joint which generate pain and may further injure the joint. In addition to pre-programmed muscle activity, reflex events are induced by landing, particularly where rapid stretch is applied to leg muscles at footstrike. No previous research in individuals with ACLD has examined the modulation of muscle activity during landings where an unexpected mechanical event changes the pre-programmed course of movement. The aim of the current study was to compare reflex muscle activation of participants with and without ACLD knees during landings on false and normal floors. This could highlight altered control strategies that affect anterior shear forces and joint instability during landings.

Methods: Subjects were 19 ACLD males and seventeen healthy male controls who performed repeated one legged landings from a box 30 cm in height and 15cm in height. In addition to normal landings, subjects also performed a single landing onto a false floor placed at a 15cm height from the solid floor. In such trials, subjects unexpectedly fell through the false floor to the solid floor below (30cm total height). The appearance of the false and solid floors were identical. EMG from vastus lateralis (VL), biceps femoris (BF) and soleus (Sol) was collected and normalised to maximum voluntary activation. Two epochs between 30-60 and 61-90 ms post landing were examined. Statistical comparisons were made across legs (ACLD, ACL intact and control) in normal 30cm landings. Additionally the ratio of EMG activity in false floor landings to that observed in normal 30cm landings was analysed.

Results: In normal landings, in both epochs, significantly less VL EMG activity was observed in the ACL deficient limb compared to the ACL intact and control limbs. Significantly decreased BF EMG activity was observed in the 31-60 ms epoch only. No significant effects were observed for Sol. Overall, false floor landings increased EMG activity in both epochs in all muscles and legs. Only VL had a different response across legs. In both epochs, the ratio of VL EMG activity was significantly greater in the ACL deficient limb compared to the ACL intact and control limbs (2.5 times controls). In both BF and Sol muscles, there was no significant difference across legs.

Conclusions: In normal landings, while reduced EMG activity in VL could impair shock absorption at landing, it might also be beneficial in decreasing anterior shear forces generated by the quadriceps early after landing. Reduced hamstrings EMG in ACLD subjects lessens their potential to decrease anterior shear forces during the landing period. In false floor landings, the exaggerated increase in VL activity observed in the ACLD limbs might improve shock absorption, but may also increase anterior shear forces and hence the likelihood of giving way.

S3 SYMPOSIUM: WHY ARE MUSCLES WEAK AFTER STROKE?

S3.1 Why Are Muscles Weak After Stroke?

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BACKGROUND AND AIMS: Following hemispheric stroke, there is typically a substantial reduction in voluntary force generation in the limbs contralateral to the lesioned hemisphere. There are several ways in which this force reduction could happen. First, there could be reduced excitatory drive from corticospinal neurons to the spinal segment. Second, there could be a disruption in motor unit recruitment and firing rate profiles, causing skeletal muscles to be activated inefficiently. Finally, there could be changes in muscle microarchitecture, making muscle contraction less mechanically inefficient. We do not know yet which potential mechanism is the most important, and indeed whether more than one mechanism may be applicable.

Methods: Eleven hemispheric stroke survivors were recruited. Each subject performed isometric elbow flexion at several designated force levels. Elbow torque and sEMG were recorded using a multiaxial load cell at the wrist, and from multiple EMG sensor arrays placed on different arm muscles.

Results: MVC Force: Most hemispheric stroke survivors presented with strongly lateralized weakness on their more affected side. Across all subjects, the affected side was 37% ± 9% weaker than the contralateral side (mean ± SEM), corresponding to 61 N ± 20 N reduction in force. However, weakness did not present uniformly across the subject pool. Five subjects were profoundly weaker on their affected side (MVC lower by more than 70N). Two subjects had moderate lateralized weakness (MVC lower by 10N to 70N). Three subjects showed little evidence of lateralized weakness (MVC not different by more than 10N). Maximum surface EMG is reduced in stroke-affected arms. MVC EMG: Maximum voluntary EMG was routinely lower on subjects' affected sides. Eight of the ten subjects had lower EMG on all affected arm sensors (BICM, BICL, BRD, medial sensor array, lateral sensor array). The remaining two subjects had lower EMG on 4/5 affected arm sensors. In the five subjects with profound weakness, biceps EMG was lower by 77% ± 4% (mean ± SEM). In the five subjects without profound weakness, biceps EMG was reduced by 45% ± 6%. Overall, deficits in maximal voluntary EMG correlated with lateralized weakness. Linear regression, surface EMG vs. Elbow force: To help interpret differences in MVC EMG, we compared the EMG/force relationship of affected and contralateral muscle. Most subjects had no differences in the slope of the EMG/force relationship across arms. In 6/10 subjects, the regression slopes were not significantly different ($p>0.05$ on all sensors). However, four subjects did have significant differences in slopes, on one or more sensors. Overall, changes in the EMG-force relationship were not correlated with deficits in MVC EMG, or with muscle weakness.

Conclusion: These results show that there is a consistent reduction in surface EMG accompanying the reduction in maximum isometric force. There is no major shift in the slope of the force-EMG relations indicating that efficiency of muscle contraction did not change measurably. Taken overall, this suggests that the primary contributor to reduction in maximum force is a reduction in central neural command.

S3.2 Altered fascicle behavior of medical gastrocnemius in chronic stroke survivors

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BACKGROUND AND AIM: Decreased force generation is one of the most common motor impairments in chronic stroke survivors, and limits functional performance in activities of daily living. Currently, the mechanisms that contribute to muscle weakness after stroke are not fully understood. In addition to decreased muscle mass, there is evidence of changes in muscle architecture after stroke (e.g., shortened fascicle length and decreased pennation angle) under passive conditions. As muscle architecture is closely related to fascicle dynamics, it is important to understand fascicle behavior under active conditions for gaining insight into the force-generating capacity of muscle. This study aims to compare fascicle behavior of paretic and non-paretic medial gastrocnemius (MG) of stroke survivors during isometric contraction at different activation levels.

Methods: Subjects (five stroke survivors) were seated upright with the knee flexed to ~10° and the foot secured to a dynamometer. Surface electromyogram (sEMG) electrodes were placed on the MG. Each subject performed isometric plantarflexion at different ankle torques: 0, 20, 40, and 60% of maximum voluntary contraction (MVC) while ankle torque, sEMG, and B-mode ultrasound images (Aixplorer, SuperSonic Imagine, Aix-en-Provence, France) were recorded. Muscle architectural parameters (e.g., fascicle length, pennation angle, and muscle thickness) were manually estimated from the ultrasound images. MG muscle activity was computed from the sEMG signals and linear regression analysis was then conducted to determine the relationship between muscle architectural parameters and muscle activity.

Results: At rest, fascicle length, pennation angle, and muscle thickness on the paretic MG decreased by 5.6% (4.6 cm vs. 4.9 cm; $p<.05$), 16.3% (17.3° vs. 20.6°; $p<.05$), and 21.4% (1.3 cm vs. 1.7 cm; $p<.05$) compared to the non-paretic side, respectively (Fig.1A). As muscle activity increased, fascicle length of both sides decreased, but changes in fascicle length during contraction of the paretic side were significantly less than in the non-paretic side (-0.05 mm/%MVC vs. -0.2 mm/%MVC; $p<.05$; Fig.1B). Pennation angle on the paretic side was significantly smaller compared to the non-paretic side (0.03°/%MVC vs. 0.12°/%MVC; $p<.05$). In contrast, muscle thickness did not change with muscle activity ($p=.893$).

Conclusions: The finding that muscle architecture on the paretic side is altered at rest, as well as during isometric contraction (i.e. minimal fascicle shortening and rotation) implies that altered muscle architecture likely affects muscle mechanics. It is plausible that decreased fascicle length is related to loss of sarcomeres, resulting in decreased force generation as well as reduced fascicle operating range which may alter joint characteristics (e.g., reduced range of motion, or early development of passive resistance force during joint rotation). These findings suggest that muscle architectural changes potentially contribute to muscle weakness after stroke. (NIDILRR no. 90SFGE0005)

S3.3 Relative Contribution of Different Altered Motor Unit Control to Muscle Weakness in Stroke

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Objective: Chronic muscle weakness impacts the majority of individuals after a stroke. The origins of this hemiparesis is multifaceted, and an altered spinal control of the motor unit (MU) pool can lead to muscle weakness. However, the relative contribution of different MU recruitment and discharge organization is not well understood. In this study, we sought to examine these different effects by utilizing a MU simulation with variations set to mimic the changes of MU control in stroke. Approach: Using a well-established model of the MU pool, this study quantified the changes in force output caused by changes in MU recruitment range and recruitment order, as well as MU firing rate organization at the population level. We additionally expanded the original model to include a fatigue component, which variably decreased the output force with increasing length of contraction. Differences in the force output at both the peak and fatigued time points across different excitation levels were quantified and compared across different sets of MU parameters. Main results: Across the different simulation parameters, we found that the main driving factor of the reduced force output was due to the compressed range of MU recruitment. Recruitment compression caused a decrease in total force across all excitation levels. Additionally, a compression of the range of MU firing rates also demonstrated a decrease in the force output mainly at the higher excitation levels. Lastly, changes to the recruitment order of MUs appeared to minimally impact the force output. Significance: We found that altered control of MUs alone, as simulated in this study, can lead to a substantial reduction in muscle force generation in stroke survivors. These findings may provide valuable insight for both clinicians and researchers in prescribing and developing different types of therapies for the rehabilitation and restoration of lost strength after stroke.

S3.4 Contributions from altered motoneuron regulation after hemispheric stroke

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Background and Aim After a hemispheric stroke, many stroke survivors exhibit impairments in their ability to voluntarily activate their muscles, manifesting often as muscle weakness or an inability to generate voluntary force. Most often, a reduction in descending neural drive and/or muscle atrophy are cited as likely contributing factors. However, there is also evidence of a reduction in motor unit (MU) firing rates, as well as an increase in the recorded electromyogram (EMG) for a given level of force in paretic muscles. Disorganization of normal MU firing patterns can compromise MU force generation. However, it is unclear whether the alterations in MU firing rates are a consequence of reduced descending drive and whether the changes in firing patterns are uniformly distributed across the motoneuron pool. In order to address these issues, we compare intramuscular single MU data collected at low forces with population motor unit data collected from a novel surface EMG at higher force levels.

Methods We tested the first dorsal interosseous(FDI) muscle with the index finger cast and inserted in a plastic interface which was attached at the proximal interphalangeal joint (PIP) to a six degrees-of-freedom load cell, on both sides of stroke survivors. To record MU activity, fine wire electrodes were inserted in two separate FDI locations in both paretic and contralateral muscles of stroke survivors. MU discharge rates during force rise were plotted for discriminable MUs. In a separate set of experiments, using an EMG sensor array, we recorded sEMG during isometric contractions of the FDI muscle over a range of contraction levels, from 20% to 60% of maximum. Using commercial software, MU action potential amplitudes and recruitment thresholds were derived for simultaneously activated MUs in each isometric contraction.

Results from the surface data were that MUs in paretic muscle were recruited over a very narrow force range with increasing force output, generating a strong clustering effect, when referenced to recruitment force magnitude. Such disturbances in MU properties also correlated well with the impairment of voluntary force generation. Our results also revealed significant changes in MU firing rate patterns in paretic FDI muscle, in that the discharge rates, characterized in relation to recruitment force threshold and to MU size, were less clearly correlated with recruitment force than in contralateral FDI muscles. Firing rates in the affected muscle also did not modulate systematically with the level of voluntary muscle contraction, as would be expected in intact muscles. These disturbances in firing properties were also correlated with the impairment of muscle force generation. Discriminated MUs from our fine wire electrodes, exhibited rate modulation impairment as well as substantial firing rate saturation on the paretic side. However, our data shows during the saturation period, multiple motor units were recruited, implying that the rate saturation was not a consequence of reduced neural drive.

O5 BACK, NECK AND SHOULDER PAIN I

O5.1 Relation between the degree of specific low back pain and activation of the erector spinae muscles during tasks of daily life

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BACKGROUND AND AIM: Specific pain located in the lumbar region (LBP) is widely disseminated in the western society and leads to a reduction of life quality. Still commonly accepted is the assumption that alterations in body posture and spine stiffness triggered by non-specific LBP can be referred to pathological changes in the erector spinae muscles. In previous studies have been already shown that non-specific LBP leads to an increase or decrease of muscular activation and a deterioration of symmetry in the erector spinae muscles situated on the left and right side of the spine. In the light of the background outlined this study investigates, whether the assumptions have been made regarding non-specific back pain can be transferred to specific LBP and whether the degree of pain correlates with these alterations in muscular activation.

Methods: 39 patients with specific LBP and 20 healthy subjects without any background of LBP took part in this study. A course of 6 exercises was designed including movements relevant to daily life. More precisely, the subjects performed Climbing Stairs (CS), Standing and Sitting (SS), 6-minute Walk Test (WT), 30-second Stand Test (ST), Static Trunk Flexion (STF) and Dynamic Trunk Flexion (DTF). Muscle activation of the m. erector spinae longissimus and m. erector spinae iliocostalis on the left and right side of the spine was measured by bipolar surface electromyography (sEMG) and the Zurich Claudication Questionnaire was collected as clinical pain score. The time synchronous detection of analog signals, whose sensors were attached in the measurement set-up, enabled the assignment of different movement phases to the corresponding sEMG. Three features including integrated EMG (IEMG), median frequency (MDF) and the correlation of activation between the erector spinae situated on the left and right side of the spine were calculated.

Results: Overall, it turned out that the pain symptomatology influences the erector spinae activation and its symmetry. The former behaves proportional to the clinical pain score, however, it is exercise and movement dependent whether the muscular activation increases or decreases in the direction of higher pain levels. A decreasing muscular activation of the erector spinae muscles over an increasing pain score have been identified in static movements as STF ($p<0.001$) and ST ($p=0.003$), and the opposite patterns have been detected in dynamic movements as CS ($p<0.001$) and SS ($p<0.001$).

Conclusion: These results prove that there is connection between pain symptomatology and erector spinae activation patterns affected by specific LBP which corresponds to the conclusions which were already drawn in patients with non-specific LBP. Besides showing pathological changes in the erector spinae muscles induced by specific LBP, the applied methodology can be used in future for the validation of therapy methods with regard to pain level improvements in patients with specific LBP.

O5.2 People with chronic low back pain show differences in the spatial distribution of erector spinae activity during an endurance task

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Chronic non-specific low back pain (LBP) is a leading cause of disability globally; in the UK it is estimated to annually cost the NHS £1.5 - £2.8 billion. It is well documented that people with LBP show different patterns of muscle behaviour which may contribute to the persistence of symptoms. In this study, high-density electromyography (HDEMG) was applied to the lumbar erector spinae (ES) during an isometric back extension task to evaluate the spatial distribution of ES activity and changes in the distribution of activity with fatigue. It was anticipated that this study would provide new insights into changes in muscle activation in people with LBP which may facilitate the development of novel exercise programmes. Thirteen people with chronic LBP (6 men, age: 27.4 ±9.7 years) and thirteen healthy controls (7 men, age: 26.5 ±5.0 years) participated in this study; for which ethical approval was granted by the University of Birmingham Ethics Committee. HDEMG signals were detected with a semi-disposable adhesive grid of electrodes (13 x 5) placed over the ES, positioned 2 cm lateral to the L5 spinous process, following skin preparation. The electrode was placed over the side of greatest pain for the LBP participants and the right side for the control group. Participants completed a supine endurance test of isometric back extension (Ito test) until task failure as HDEMG was recorded simultaneously. The EMG root mean square (RMS) and the mean power spectral frequency (MNF) were averaged across the entire grid and were expressed in 10% intervals of the endurance time. The RMS was computed for each location of the grid to form a topographical map of the EMG amplitude. To characterize the spatial distribution of muscle activity, the two coordinates of the centroid of the RMS map (x and y-axis coordinates for the medial-lateral and cranial-caudal direction, respectively) were calculated and expressed in 10% intervals of the endurance time. People with LBP had significantly lower endurance compared to the control participants (LBP: 186.2±72.3s, controls: 283.0±33.0s; $p<0.01$). Overall, the RMS averaged across the grid was systematically higher in control participants ($p<0.05$) compared to the LBP participants across the entire contraction. There was no difference MNF between groups, however the y-axis coordinate of the RMS map was, on average, 12 mm more cranial in the LBP group over the duration of the task ($p<0.05$). Moreover, the LBP group showed significantly less displacement of the y-axis coordinate of the RMS map across the duration of the contraction (LBP:1.4±1.1mm, controls: 2.1±1.6mm; $p<0.05$). These results show that the LBP group utilised a different motor strategy to perform the endurance task which was characterised by greater activation of the ES more cranially and less redistribution of activity during the task. This different motor strategy likely contributed to the lower endurance for the LBP group and may have relevance for ongoing pain.

O5.3 Accuracy of Trunk Muscle Activation Patterns to Predict Low Back Reinjury

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BACKGROUND AND AIM: The risk of experiencing a low back injury (LBI) is explained by psychosocial, environmental and individual factors1. While much research on individual factors have considered anthropometrics and demographics, differences in muscle activation patterns offer person specific features that have predictive potential2,3. Yet, the accuracy of such prediction is unknown. The purpose of this study was to determine the sensitivity and specificity of trunk muscle activation patterns to predict future reinjury.

METHODS: Fifty-five recovered LBI participants (4-12 weeks post injury, minimal pain and disability) performed a series of highly controlled leg loading tasks shown to differ between participants who reinjure2. Surface electromyograms (EMG) were digitized from 24 trunk muscle sites (12 abdominal and 12 back extensors) at 1000Hz, full-wave rectified, low-pass filtered (6 Hz), time normalized to 100% task and amplitude normalized to maximum voluntary isometric contractions. EMG ensemble-average waveforms were calculated for each muscle site and participant. Principal component (PC) analysis models constructed for each task and for the abdominal and back sites separately captured key waveform features. At 1-year follow-up, participants were grouped as reinjury (RE, n=29) or no-reinjury (NoRE, n=26) based on self-reported LBI limiting activity for > 3 days. Mixed model ANOVAs (group, muscle) were conducted on PC scores. Significant features (α=0.05) were entered into a stepwise linear discriminant analysis model (α=0.15) to predict reinjury. Model accuracy was tested using leave one out cross-validation.

RESULTS: The discriminant analysis model identified 5 features to predict group. PC1 captured higher overall activation and PC4 captured a relative increase in activation of the abdominals after left leg lift, and a decrease mid-left leg lower in the RE group (Fig). Three features including higher lateral back extensor activation (PC1) (Fig), a greater difference between the overall activation of lateral and medial sites (L-M PC1), and a greater difference between right leg lift/lower activity versus no leg support (PC2) were found in the RE group (Fig). The sensitivity, specificity and accuracy of this model was 80.8 (65.4), 72.4 (72.4) and 76.5 (69.1)% respectively, with cross validated values in brackets.

CONCLUSIONS: A combination of individual activation patterns alone predicted reinjury with sensitivity and specificity comparable to Marras et al. who included psychosocial, environment and individual (kinematics) features1. While greater activation (PC1 abdominals) implicates strength deficits, spatial differences including, a suppression of the medial sites (PC1 L-M) and altered temporal responses (PC2 and PC4), suggests sensorimotor errors and reduced stiffness during different phases of the leg loading task for the RE group. Performance metrics were very good but the drop in sensitivity requires further investigation of overtraining.

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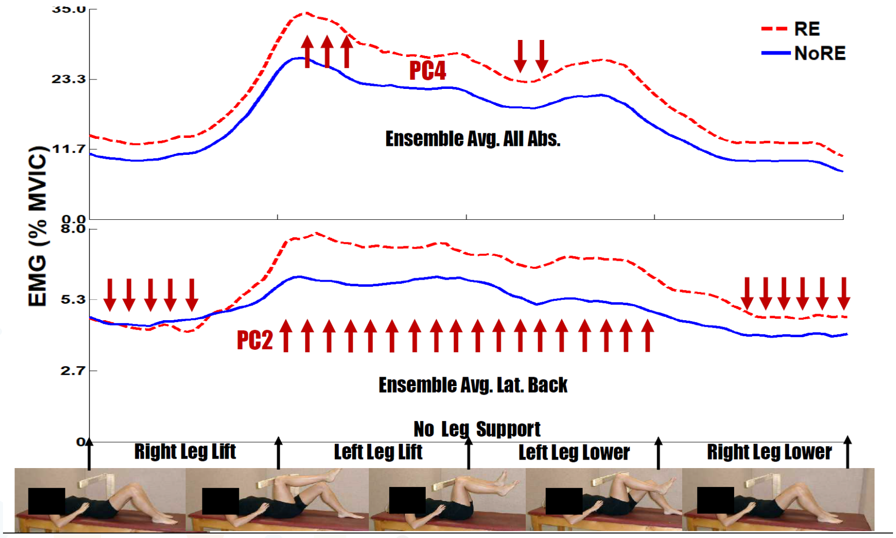
RE
NoRE
PC4
Ensemble Avg. All Abs.
EMG (% MVIC)
35.0
23.3
11.7
0.0
8.0
5.3
2.7
0
PC2
Ensemble Avg. Lat. Back
No Leg Support
Right Leg Lift
Left Leg Lift
Left Leg Lower
Right Leg Lower

O5.4 The effects of lumbar posture on back extensor torque and trunk muscle activation in patients with chronic low back pain during maximal lifting.

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BACKGROUND AND AIM: Back extensor strength and trunk muscle recruitment are considered important when rehabilitating patients with chronic low back pain (LBP). However, to date, there is dearth of information on how trunk extensor strength and activation in this patient group is influenced by lumbar posture during functional activities, such as lifting. The aim of this study was to investigate the effect of lumbar posture on back extensor torque and trunk muscle activity in individuals with chronic LBP during a simulated lifting task.

Methods: A case-control, repeated measures study design compared twelve chronic LBP patients with twenty healthy individuals. Participants adopted three lumbar postures (fully extended, fully flexed and mid-range) while exerting a five second maximal isometric back extension in a lifting posture with the knees flexed at 45 degrees. In each posture, the muscle activity of the paraspinal muscles (upper (UES) and lower erector spinae (LES), and multifidus) and internal oblique (IO) was recorded using surface electromyography (EMG). EMG of the paraspinal muscles was expressed as a percentage of maximal voluntary contraction measured in the Biering-Sorensen position. A chest harness connected to a 3D floor mounted force gauge (AMTI, USA), via a metal chain, provided a measure of maximum isometric voluntary trunk extensor force. A nine-camera motion analysis system (Qualysis Medical AB Sweden) recorded body position, which was used in conjunction with kinetics to estimate trunk extensor torque. Neuromuscular efficiency was expressed as a ratio of peak torque to paravertebral muscle activity. Data was analysed using analysis of variance (ANOVA), with an alpha level of 0.05.

Results: Both chronic LBP and controls increased trunk extensor torque and reduced activation of the UES, LES and multifidus when changing from an extended to a fully flexed posture, with corresponding improvements to their neuromuscular efficiency ($P<0.05$). Across postures, the LBP group had significantly lower levels of multifidus activation when compared to the UES and LES ($P<0.05$). In contrast, controls showed similar changes in muscle activity across all extensor trunk muscles in response to changes in lumbar posture. Lumbar posture did not influence IO activation levels, but the LBP group displayed higher levels of abdominal muscle co-contraction than the controls.

Conclusion: In chronic LBP, changes in lumbar posture affects the ability to exert an extensor torque in a similar way to that of healthy participants, whereby increased lumbar flexion results in greater extensor torque and improved neuromuscular efficiency. However, patients with chronic LBP may achieve this using muscle activation strategies that exhibit a greater contribution of erector spinae than multifidus and are more reliant on abdominal muscle co-contraction.

06 MOTOR CONTROL II

O6.1 Distinct neural control of intrinsic and extrinsic muscles of the hand during isometric single finger presses

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BACKGROUND: Most common tasks in which we use our hands involve simultaneous use of multiple fingers. Single finger movements lead to unintentional activation of non-instructed fingers, usually called enslaving. Mechanical and neural factors that characterize the control of common multi-finger movements are associated with enslaving. To investigate the neural constraints, both muscles in the lower arm (extrinsic) and within the hand (intrinsic) should be considered as they are involved concurrently in single finger control. This study aimed to investigate the amplitude modulation of both intrinsic and extrinsic muscles during isometric single finger presses.

Methods: Twelve participants performed single finger flexion presses at 20% of their maximum force capacity of the index, middle, ring, and little finger. The experiment consisted of 16 trials of each finger. During the trials, both force and electromyography (EMG) were recorded simultaneously. EMG activity was recorded from 8 electrode pairs in the hand, and two grids of 30 electrodes on the lower arm, targeting the muscles associated with flexion and extension of the fingers. Of these 30 electrodes, 1 bipolar electrode pair was associated with a single finger for both flexion and extension by selecting the channel with the highest cross-covariance between the EMG and force signal. Statistical analysis of the EMG data was performed with the Kruskal-Wallis test due to the non-normality of the data.

Results: Analysis of the forces showed enslaving in the non-instructed fingers, with significantly higher enslaving for the neighbouring fingers ($p < 0.001$ in all cases), except for when the index finger was instructed finger. We found significant differences in EMG amplitude between the investigated muscles when split up per instructed finger ($p < 0.001$ in all cases). Intrinsic muscles, both agonistic and antagonistic, inserting on the instructed finger were more active that the intrinsic muscles associated with the non-instructed fingers. Contrary to the intrinsic muscles, extrinsic muscles showed a broad base activation in both agonistic and antagonistic muscles, independent of the instructed finger. Only the agonistic extrinsic muscles associated with the instructed finger were additionally modulated on top of this base level. This modulation was not present in the antagonistic extrinsic muscles.

Conclusion: This study shows a distinct neural control of intrinsic and extrinsic hand muscles during single finger isometric force tasks. While both agonistic and antagonistic intrinsic muscles exhibit individuation, extrinsic muscles revealed a base activation independent of the instructed finger. Only the agonistic extrinsic muscles showed some modulation on top of this base associated with the instructed finger. Our results suggest that the individuation of the intrinsic muscles are not sufficiently counteracting the broad activation of the extrinsic hand muscles to prevent enslaving.

O6.2 Physical interaction with a circular constraint

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BACKGROUND AND AIM: Knowledge of the control strategies used for human physical interaction could provide insight for the design of more effective robotic rehabilitation, and allow for applications to a broader range of functional tasks. In this work, we examined the effect of speed and turning direction on arm movements while interacting with a crank, a horizontal planar circular constraint. The crank provides constant inertia, constant curvature, and requires no mechanical work. Unconstrained motion studies of multi-joint reaching have clearly documented patterns evident in hand kinematics external to the body, which are not observed in joint torques, joint kinematics, or muscle forces. Hypothesis: The same control organization (i.e. motion control in extrinsic task-relevant coordinates) observed in unconstrained actions is 're-purposed' to accomplish constrained motion. Effects that may make motion control difficult, such as closed-chain inertial dynamics, limited neuromuscular response time, and activation-dependent motor noise, all decline with speed. Therefore, subject performance should be best at slow speeds.

Methods: Ten healthy right-handed subjects were recruited for the study. The crank (radius 10.29 cm) was equipped with a position encoder at the center and a 6-axis force transducer at the handle. The upper arm was suspended in the plane of the constraint while the subject's shoulder was constrained, and the wrist was braced. For the first set of trials, subjects were instructed to perform continuous turning at their preferred speed. Then they were provided with visual velocity feedback and asked to turn at one of three constants speeds: slow (0.075 rev/s), medium (0.5 rev/s), and fast (2.0 rev/s).

Results: Subjects successfully turned the crank at a constant speed with some velocity fluctuations. At medium speeds (comparable to subjects' preferred speed) and fast speeds (close to the fastest subjects could turn the crank), the observations were consistent with moderately imperfect execution of a motion control strategy. Speed coefficient of variation was similar for the fast and medium speed movements but, surprisingly, it increased substantially at the slowest speed: almost double that of the medium speed movements (29% vs. 15%) and two-and-a-half times greater that of the fast movements (29% vs. 12%). Furthermore, mean normal force was not significantly different from zero in the medium speed condition. However, at slow speeds subjects exerted mean compressive normal forces (which are de-stabilizing).

Conclusions: At slow speeds, a motion controller would perform ideally and result in the smallest errors. In contrast, at slow speeds we observed a large increase in the coefficient of variation of speed and compressive mean normal forces. These observations indicate that the human motor control system may be more complex than a simple motion controller.

SUPPORT: NSF EAGER 1548501, NSF NRI 1637824 and the Newman Fund.

O6.3 Elbow joint angle and biceps brachii muscle-length separately influence spinal, but not corticospinal, excitability to the biceps brachii

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Background and Aim: Forearm rotation significantly alters corticospinal and spinal excitability to the biceps brachii during rest and during rhythmic arm cycling.
Conclusions from these studies have suggested that rotation of the forearm is the driving mechanism. However, rotation of the forearm (pronation - supination) alters the biceps brachii muscle length. Thus, the purpose of this study was to separately examine the influence of both elbow joint angle and muscle length on corticospinal and spinal excitability to the biceps brachii.

Methods: Eleven, male participants were recruited for this study. Corticospinal and spinal excitability to the biceps brachii were measured using motor evoked potentials (MEPs) elicited via transcranial magnetic stimulation (TMS) and cervicomedullary-evoked potentials (CMEPs) elicited via transmastoid electrical stimulation (TMES), respectively. Both MEP and CMEP amplitudes were made relative to maximal compound muscle action potentials (Mmax) elicited under the same experimental conditions. In a seated position with the upper-arm supported on a table (shoulder flexed to 90°), the participant's forearm was secured to a custom-built apparatus and placed into five different postures; 1) forearm neutral, 90° elbow flexion, 2) forearm supinated, 90° elbow flexion, 3) forearm pronated, 90° elbow flexion, 4) forearm supinated, 78° elbow flexion, and 5) forearm pronated, 113° elbow flexion. Musculoskeletal modelling software, OpenSIM (Delp et al., 2007) was used to determine biceps brachii muscle length for postures 1-3 and the elbow joint angles (postures 4-5) were selected to maintain biceps length and account for the effect of forearm rotation. In these five postures, MEPs and CMEPs were elicited during two different conditions; rest and an isometric contraction of 10% of biceps brachii maximal EMG. Positions were pseudo-randomized.

Results: At rest, a main effect of forearm rotation was found on MEP amplitudes, with amplitudes largest during forearm supination and smallest during forearm pronation ($P < 0.05$). This finding was independent of elbow joint angle. There were no differences in CMEP amplitudes when the elbow joint was fixed at 90°, but when muscle-length was controlled, a main effect occurred across forearm postures. The largest CMEP amplitudes were found for forearm pronation and the smallest for forearm supination ($P < 0.05$). During the isometric contraction trials, there were no significant differences across forearm postures for either MEP or CMEP amplitudes.

Conclusions: These results suggest that the influence of forearm rotation on corticospinal excitability, but not spinal excitability to the biceps brachii, is independent of joint position or muscle length.

O6.4 Low-frequency fluctuations in motor output are distinctively associated with beta-band and gamma-band neural oscillations during steady cocontracion

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BACKGROUND AND AIM: Steady cocontraction of antagonistic muscles is essential for producing steady joint stiffness to maintain posture. Associations between low-frequency fluctuations in motor output and higher-frequency neural oscillations have been suggested during steady contraction of agonist muscles, but the presence and characteristics of such associations during cocontracion of antagonistic muscles are unknown. The purpose of this study was to understand the associations between low-frequency fluctuations in motor output and higher-frequency neural oscillations during steady cocontraction in healthy humans.

METHODS: Forty healthy young adults used their right arm to perform isometric steady contraction and cocontraction of the wrist flexor and extensor muscles in the neutral position. Six trials were performed in flexion and cocontraction in random order. Contraction intensity was 15% of maximal voluntary activation of the corresponding muscles with real-time visual feedback. Electroencephalogram (EEG) and surface electromyogram (EMG) were analyzed from the left primary motor cortex and the flexor carpi radialis in the right arm, respectively. Powers of rectified EMG (rEMG) < 1 Hz and 1-3 Hz (delta-band) were determined as the magnitudes of low-frequency fluctuations in motor output. Powers in beta-band (14-35 Hz) and gamma-band (36-75 Hz) were determined in EEG and interference EMG as potentially associated higher-frequency oscillations. All powers were normalized to the corresponding total power ≤ 75 Hz and averaged across 6 trials in each contraction type.

RESULTS: During steady contraction of the flexor muscles, the only significant correlation was a positive correlation between gamma-band power in EEG ($r = 0.314$, $P < 0.05$) and fluctuations in rEMG < 1 Hz across subjects. In comparison, distinct and more abundant associations were found during steady cocontraction. Positive correlations with gamma-band power in interference EMG were found with fluctuations in rEMG < 1 Hz ($r = 0.436$, $P < 0.01$) and also in delta-band (1-3 Hz) rEMG ($r = 0.337$, $P < 0.05$). Negative correlations were found between beta-band power in EEG and fluctuations in rEMG < 1 Hz ($r = -0.356$, $P < 0.05$), between beta-band power in interference EMG and fluctuations in rEMG < 1 Hz ($r = -0.448$, $P < 0.01$), and between beta-band power in interference EMG and fluctuations in delta-band rEMG ($r = -0.337$, $P < 0.05$).

CONCLUSIONS: These results demonstrate distinct and more abundant associations during cocontraction compared with agonist contraction, and suggest that healthy individuals with less fluctuations in low-frequency motor output tend to have less gamma-band neural oscillations and greater beta-band neural oscillations during steady cocontraction. The findings may serve as a proof of concept in developing interventions that can differentially modulate neural oscillations in specific frequencies for improving steady motor output during steady cocontraction.

O7 GAIT & POSTURE I

O7.1 Tri-axial changes in postural sway predictability in people with Parkinson's disease over 36 months

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BACKGROUND AND AIM: Parkinson's disease (PD) is the second most common neurodegenerative disease with a worldwide prevalence greater than 1% in adults over 70 [1]. Postural instability, a known predictor of falls with consequential impact on wellbeing [2], is a common motor feature in people with PD. Management of postural instability is challenging as it is often resistant to dopaminergic therapy. Cognitive dysfunction is also frequently present. This study aimed to investigate features of postural control through nonlinear analysis of trunk accelerometry data. We hypothesised that as postural control becomes more goal directed involving conscious control, movement patterns become more irregular and less predictable. Additionally, we hypothesised that there would be a positive correlation between postural regularity and cognitive function. A second aim was to investigate how these features progress over a 36 month period.

Methods: The study group consisted of 50 people diagnosed with PD and 59 healthy older adults, recruited as part of an incident cohort study (ICICLE-GAIT). The PD participants were tested approximately 1 hour after medication intake. Participants stood still for 2 minutes, eyes open and arms by their side. A single tri-axial accelerometer (Axivity AX3, York, UK) on the lower back recorded acceleration. Measurements were taken at 18, 36 and 54 months after recruitment. Sample entropy (SampEn), which measures signal predictability, was calculated for the accelerometry data. Cognition was assessed by neuropsychological tests including the Montreal Cognitive Assessment (MoCA) and Mini-Mental State Examination (MMSE).

Results: Results indicated that SampEn was greater ($p<0.001$) for the PD group at all three time-points and along all three axes. However, there was no increase of SampEn with disease progression. SampEn in the anteroposterior direction was significantly less ($F_{2, 477}=62.0$, $p<0.001$) than in the mediolateral and vertical directions. Higher SampEn values were associated with greater cognitive impairment.
Conclusions: Loss of constant fine adjustments of posture due to impaired sensorimotor integration and disturbance of habitual motor control pathways may explain the decreased postural predictability. The absence of any decrease in postural regularity over time suggests that adaptive postural control mechanisms are already well integrated at 18 months post-diagnosis. Greater postural predictability in the anteroposterior plane indicates less impairment of automaticity supporting previous findings [3]. The relationship between postural measures and cognitive function points to shared neural pathways. Further studies will determine how nonlinear parameters relate to underlying neural correlates and clinical correlates.

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O7.2 Small, movement-dependent postural perturbations substantially alter postural control in healthy young adults

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BACKGROUND AND AIM: Understanding of postural control is important for prevention of falls, a severe health and societal problem. Commonly, external perturbations mimicking circumstances of falling, such as unexpected trips, slips or support surface movements, are used to study postural control. However, among older adults, a common cause of falling are erroneously generated shifts of bodyweight [1]. To mimic these self-generated perturbations, we developed a novel experimental paradigm utilizing a robotic system to deliver real-time, movement-dependent support surface perturbations in the medio-lateral (ML) direction.

METHODS: Healthy young (24.1 ± 3.3 years, n = 15) participants stood still on the robotic platform, with their feet hip-width apart, in four conditions: with the eyes opened, closed and while performing two different cognitive tasks. The robotic platform delivered a continuous perturbation to mimic weight-shifting errors. The perturbation was a series of ML support surface translations, which corresponded to participant's COM movement in real-time, effectively doubling the COM sway [2]. Each of the abovementioned four conditions was performed with and without the perturbation and postural sway relative to the support surface movement was analyzed in terms of the range, standard deviation (SD), root mean square (RMS), and mean power frequency (MPF) of the center of pressure (COP), for ML and anterio-posterior (AP) directions separately. We performed two repeated measure ANOVAs to investigate the effects of vision x perturbation and cognition x perturbation.

RESULTS: Even though the perturbations were small, they led to a significant increase in all indicators of ML postural sway (range $p \leq 0.001$, SD $p \leq 0.001$, RMS $p < 0.005$, and MPF $p \leq 0.001$). Cognitive tasks increased the range of postural sway in ML direction ($p = 0.048$), while the elimination of visual information increased MPF in ML direction ($p = 0.001$) and SD ($p \leq 0.001$), RMS ($p = 0.001$) and range ($p \leq 0.001$) in the AP direction. Additionally, we found an interaction of vision with the perturbation ($p = 0.045$), indicating that vision deprivation exacerbated the perturbation effect on COP movement range.

CONCLUSIONS: This sophisticated perturbation elicited direction-specific responses in healthy young adults despite its small amplitude. Increased MPF indicates a change in postural control strategy, which was insufficient for controlling the increased postural sway, as evident from higher variability and range of ML COP sway. Moreover, we confirm the importance of cognitive resources and visual information for postural control, but could only find an interaction effect between perturbation and vision, possibly due to an insufficiently challenging postural task.

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O7.3 Long-term retention of split-belt walking reveals differences in spatiotemporal gait adaptation and dynamic balance control

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BACKGROUND AND AIM: Motor adaptation is an important part of motor learning and can be studied in gait using a split-belt treadmill. A split-belt treadmill (with two belts, one under each foot) imposes spatiotemporal gait asymmetry upon a person, by making the participant walk faster with one leg than the other, while it also perturbs mediolateral balance. By determining which information is retained or forgotten after repeated exposure to the split-belt, we expect to identify independent processes involved in locomotor adaptation.

Methods: Fifteen healthy young adults were exposed to a single session of split-belt adaptation, and were exposed to the same protocol three weeks later. The protocol contained six minutes of tied-belt gait (warm-up/baseline, alternating 0.7, 1.4, 0.7 ms-1), nine minutes of split-belt gait (adaptation, left:right 0.7:1.4 ms-1), and five minutes of tied-belt gait (re-adaptation, 0.7 ms-1). We measured ground reaction forces, moments of force, center of pressure and (extrapolated) center of mass positions, to calculate Double Support Symmetry (DSS), Step Length Symmetry (SLS) and mediolateral Margins of Stability (MoS) [2]. The magnitude of perturbation and adaptation rate were examined to assess retention of adaptation.

Results: Symmetry in step lengths (SLS) showed a lower initial perturbation and adapted to split-belt gait quicker on second exposure. Dynamic balance control parameters (MoS) and symmetry in double support durations (DSS) showed little to no retention of the initially learned gait pattern.
Conclusions: The results show that a single exposure to split-belt gait results in a smaller perturbation of gait and a quicker adaptation on second exposure. The information about adaptation of step lengths was clearly retained much better than adaptation of dynamic balance control and double support durations. This study shows that a single bout of locomotor adaptation leads to quicker and easier relearning after a three-week period.

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O7.4 Structure of surface EMGs from intrinsic foot muscle is affected by postural task demand

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BACKGROUND: Linear measures of the myoelectric signal, such as mean amplitude or activation duration, do not provide information on the time dependent variability in activation patterns that occur over the course of a movement task. Temporal organization (or structure) of variability in EMG signals is neither random nor independent of past or future events. Quantifying features of EMG signal structure should therefore provide insight into the degree of challenge a task poses to the sensory-motor system. Here we therefore use a measure of the time scale over which signal structure persists, Entropic HalfLife (EnHL), to determine the effects of different postural balance control challenges on intrinsic foot muscle EMG signal properties. AIM: i) quantify EnHL for the intrinsic foot muscles during postural tasks; ii) investigate spatial variation in EnHL values across the plantar foot surface.

Methods: A 64 channel surface electrode array was used to record EMG from the plantar region of the foot from seventeen healthy participants (weight: 74.3 ± 14.3 kg, height: 175.7 ±9.4 cm) who performed two-foot, one-foot and two-foot tiptoe standing. EMGs were processed with wavelet analysis to provide a measure of total signal intensity. Intensity envelopes were resampled over increasing time scales and analysed using sample entropy, to enable the time scale at which the signal transitioned from an ordered to a random structure to be quantified (EnHL). Longer EnHL indicates signal structure is maintained or persists over longer time periods. To determine whether EnHL truly reflected structure of recorded signals vales were compared with EnHLs calculated from phase randomized surrogate signals, generated from a randomly selected sub-portion of trials. If the EnHL in the original signals was related to the signal structure EnHL values of physiological signals should be greater than the EnHL from the surrogate signals. The spatial distribution of EnHL across the array was quantified by calculating the centre of gravity (CoG) of segmented channels with both the longest and shortest EnHLs and the area of these two regions was also calculated.

Results: EnHL values ranged between 12 - 38 ms for the two-foot tiptoe; 11 - 35 ms for one-leg stance; and 8 - 28 ms for two-foot stance. EnHL values were significantly greater than those from the surrogate signals ($p<0.05$). The lowest median values occurred during two-foot stance (12.5 ms) and the highest during two-foot tiptoe (22.8 ms), with significant differences occurring between each task ($p<0.05$). The location of EnHL CoG for both shorter and longer EnHLs for the three tasks was confined between 10-60% of the width of the foot and 5-50% of the length of the foot, corresponding to the location of the flexor digitorum brevis.

Conclusion: EnHL in intrinsic foot muscles is affected by the balance demand of the task, with greater signal structure associated with the more challenging two-foot tiptoe task.

S4 SYMPOSIUM: MULTIMODAL BIOMARKERS OF MOTOR PERFORMANCE, IMPAIRMENT AND RECOVERY DERIVED FROM PHYSIOLOGICAL MEASUREMENTS

S4.1 Clinical applications of synergy analyses to evaluate pediatric movement disorders in cerebral palsy and muscular dystrophy.

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Muscle synergy analyses have been applied across a range of human motions and provides a lens through which to view how the neural system controls our bodies. Children with movement disorders form compelling populations for studying synergies, as these children represent heterogeneous populations with altered motor control in need of improved methods for assessment and treatment. Synergies are calculated from experimentally measured electromyography (EMG) data using matrix factorization algorithms. Synergies are small numbers of muscle groupings that are commonly activated during tasks such as walking. How well the computed synergies represent the originating EMG data can be expressed by means of a summary measure: the total variance accounted for (tVAF). Our group has been using tVAF by one synergy, tVAF1, as a measure of motor control and synergy complexity to evaluate the neuromuscular control of children with cerebral palsy (CP) and Duchenne muscular dystrophy (DMD). CP impacts ~3 out of every 1000 children, and hinders movement both directly through impaired control, and indirectly through changes to the musculoskeletal system. Since CP is caused by an injury to the brain, we sought to evaluate whether measures from synergy analyses can be used to quantify impaired control and inform treatment planning. Similar to other neurological impairments, such as stroke [1], we found that children with CP demonstrate lower synergy complexity during walking than typically-developing (TD) peers, and that synergy complexity scales with impairment level [2]. In contrast, since DMD is caused by a genetic mutation that impacts muscle, and is not neural in origin, we have demonstrated that synergy complexity is similar between TD and DMD children. Although both populations have impaired movement, these results highlight that for children with CP, altered synergies are indicative of simplified control, and not purely a consequence of impaired gait and its associated biomechanical constraints [3]. Quantifying motor control is important as clinicians have long-held the belief that impaired motor control leads to worse treatment outcomes. Applying synergy complexity as a measure of motor control in CP, we found that pre-treatment synergies are associated with post-treatment changes in gait [4]. We found that, after controlling for pre-treatment kinematics and walking speed, higher synergy complexity (closer to TD) was associated with better outcomes after treatment, across a variety of treatments and two clinical centers. Despite changes in gait following treatment, we have demonstrated that there are minimal changes in synergy complexity after treatment. These findings indicate that synergy complexity may be a static level of overall motor control and may be most useful for identifying individuals at risk for poor outcomes after treatment.

References: [1] Clark 2010, J Neurophysiol, [2] Steele 2015, DMCN, [3] Kutch 2011, J Biomech, [4] Schwartz 2016, DMCN.

S4.2 Biomarkers of proportional recovery from upper and lower limb impairment after stroke

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BACKGROUND AND AIM: The ability to live independently after stroke depends on the recovery of motor function. Motor recovery is a complex process that combines spontaneous neurobiological elements in the initial days and weeks after stroke. The resolution of motor impairment is a useful model of spontaneous recovery. For instance, in several studies undertaken in different countries with varied rehabilitation services, it has been shown that upper limb impairment resolves by approximately 70% of the maximum available improvement, for a majority of patients. I will summarise studies where we examined potential biomarkers of proportional recovery from upper and lower limb (UL and LL) impairment.

METHODS: Across three studies (2 UL, 1 LL) with >200 participants, clinical, neurophysiological and neuroimaging assessments were made within 2 weeks of stroke, with follow-up assessments at 12 (studies 1-3) and 26 (study 1) weeks. Motor impairment was evaluated using the Fugl-Meyer (FM) impairment scale (range 0 - 66 for UL; 0- 34 for LL). The FM scale is a reliable and validated measure of UL and LL impairment. The main measure of interest was ΔFM between 2 and 12 (or 26) weeks. TMS was applied over the lesioned hemisphere to elicit motor evoked potentials (MEPs) recorded from surface EMG of extensor carpi radialis (ECR, UL) or tibialis anterior (TA, LL) to determine if MEPs were present or absent (MEP+/-). Age, sex, hemisphere affected, BDNF genotype, fractional anisotropy asymmetry, initial impairment score, MEP status, UL/LL therapy dose were entered as potential predictors in linear regression models of ΔFM. Proportional recovery was also examined in measures of MEP resting motor threshold.

RESULTS: Across all studies recovery took the form $\Delta FM = \beta \times$ initial FM, where β reached plateau around 0.7 by 12-26 weeks post-stroke. For UL studies, MEP status was the best predictor of proportional recovery from UL impairment such that only those who were MEP+ obtained $\beta = 0.7$, regardless of their initial impairment and independent of UL or LL therapy dose. MEP- patients made slower or no recovery, and MRI variables could differentiate between these two possible outcomes. For MEP+ patients, ΔRMT exhibited similar dynamics to ΔFM. Proportional recovery was present in patients with haemorrhagic as well as previous stroke. For LL study, ΔFM was independent of MEP status and MRI variables and predicted solely by initial FM.

CONCLUSIONS: A 70% proportional recovery from motor impairment is ubiquitous for a subset of patients with viable descending neural pathways. For the upper limb, these descending pathways reflect corticospinal neurons and their functional status can be determined within days of stroke. Lower limb recovery may rely more heavily on brainstem-mediated pathways that aren't susceptible to motor cortex TMS.

S4.3 Neurophysiological Biomarkers extracted from high-density EMG

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INTRODUCTION: Muscles are controlled by neural signals sent from the spinal cord by pools of motor neurons. In the past years, several decomposition techniques have been developed, allowing to decode the activity of the motor neurons from high-density EMG (HD-EMG) recordings. These techniques have been successfully applied in the study of neurophysiology and motor control and have helped shed light on the strategies that the CNS employs when recruiting muscles for movement and force generation. Information on the synchronization in firing activity across the motor neurons can also be used to derive biomarkers associated with the changes in neural activity that incur after acute events or gradual changes in the neurophysiological capabilities. In this work, we present three examples of biomarkers extracted using HD-EMG. Specifically, we show how the synchronization of motor units discharges changes in elderly individuals, in amputees that underwent targeted muscle reinnervation (TMR) and in acute stroke patients.

Methods: In the three studies we present we employed HD-EMG recordings consisting of arrays of 64 sensors directly applied on the analysed muscles. A blind source separation technique was used to estimate the firing patterns and the discharge rates of the motor units activated in the muscles during the different tasks. We estimated the coherence profiles between the different motor unit discharge rates. Coherence represents an index of the synchronization of the motor units and its spectral characteristics have been shown to correlate with the different components of the neural command. In the elderlies and in the acute stroke patients we recorded the activity of the Tibialis Anterior (TA) during force-matching isometric dorsi-flexion movements. In the TMR patients we recorded the activity of the radial nerve re-innervated in the short head of the biceps muscle.

Results: In the elderly population we found increased oscillations of common input to motor neurons at low frequencies and a decrease in the relative strength of gamma oscillations, that are correlated with the descending activity of the motor cortex. In the TMR patients we show that the control of motor neurons and their synaptic input following reinnervation is remarkably similar to the one of the physiological innervation in healthy individuals, though with reduced common drive at some frequencies. Finally, in the stroke population, we show increased coherence at around 13 Hz, a component that is commonly suppressed in the healthy controls.

Conclusions: Our results demonstrate that it is possible to successfully utilize features describing the synchronization of the different motor units extracted from the decomposition of HD-EMG recordings as specific biomarkers of the neuronal activity. These features could possibly be used to track impairment and recovery in different populations by giving direct information on the command signals generated by the motor system.

S4.4 Neuroimaging-derived biomarkers of chronic pelvic pain in the motor system

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BACKGROUND AND AIM: Urologic chronic pelvic pain syndrome (UCPPS) is a major healthcare burden for which we have a limited understanding of mechanism and no established treatments with evidence of effectiveness. Physical therapy, targeting improved pelvic floor muscle control, has demonstrated early promise in reducing pain in the UCPPS population. However, the underlying source of impaired pelvic floor muscle control in the nervous systems remains unknown, and thus the avenues for improving therapy are currently limited. Here we aim to identify biomarkers of UCPPS in the nervous system, and determine if these biomarkers can be therapeutically targeted to reduce UCPPS pain.

Methods: Electromyographic (EMG) data from pelvic floor muscles were collected using a medical-grade rectal EMG sensor, which provided a bipolar recording from two bar electrodes, 12 mm apart, with dimensions 30 mm by 7 mm, mounted longitudinally along a cylindrical plug-type applicator. Resting-state functional magnetic resonance imaging (fMRI) data were collected at 3 tesla to quantify local brain activity and functional connectivity among brain regions. Repetitive transcranial magnetic stimulation (rTMS) was used in both high-frequency (HF, 10 Hz, 10 seconds on 50 seconds off, 2000 pulses) and low-frequency (LF, 1 Hz, continuous, 2000 pulses) modes to examine the effect of non-invasive stimulation on UCPPS pain, resting pelvic floor muscle EMG activity, and resting-state brain activity.

Results: We first demonstrate that fMRI-derived biomarkers of UCPPS at the brain level are focused in regions of supplementary motor area (SMA) that have direct projections to spinal motor neuron pools controlling pelvic floor muscles. We then show that inter-individual differences fMRI-derived biomarkers of resting-state SMA function appear to be related to EMG-derived biomarkers of pelvic floor muscle function, both in terms of resting tone as well as the strength of the muscle synergy between pelvic floor and other lower-limb muscles. We finally show preliminary evidence that HF-rTMS of SMA can reduce UCPPS pain, improve pelvic floor muscle function, and normalize fMRI-derived biomarkers of resting-state SMA function that distinguish UCPPS patients from healthy controls.

Conclusions: Biomarkers of UCPPS at the brain level are focused in the motor system that controls pelvic floor muscles. Targeting the motor system with non-invasive stimulation may reduce UCPPS pain.

S4.5 EMG-derived muscle-synergy patterns as recovery biomarkers in stroke survivors: Results from a Multi-Center Collaboration

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BACKGROUND AND AIM: For any motor act, the CNS must assemble a coordinated pattern of muscle activities to achieve the intended motion and stabilize the joints whose motions are undesired. The computations behind this assembly are extraordinarily complicated, in that the hundreds of muscles spanning the hundreds of joints constitute a large search space of motor commands even for an apparently simple movement. The CNS may circumvent this complexity by generating muscle commands through the combination of a manageable number of pre-specified units, each of whose activation would simultaneously recruit a specific group of muscles. These units, variously called motor primitives, neuromotor modules, or muscle synergies, are in essence neural mechanisms for synchronizing motoneuronal activities for purposeful motor behaviors. Recent rodent optogenetic experiments of ourselves and others have argued that muscle synergies are encoded by spinal excitatory interneurons that are modulated by proprioceptive and descending drives. A similar organization may also exist in humans, as indicated by our recent EMG data obtained from human subjects during lower-limb adaptation. Given the plausible neural origin of muscle synergies, it is sensible to ask whether altered muscle-synergy patterns in the affected arm of stroke survivors may serve as indicators of motor impairment, and whether distinct synergy patterns may predict rehabilitative outcome.

Methods: We explore these questions by longitudinally tracking upper-limb muscle synergies (16 muscles) in diverse survivors with unilateral brain lesions (N=60) from 3 research centers (San Camillo Hospital, Venice; Spaulding Rehab Hospital, Boston; and Chinese University of Hong Kong) undergoing 1 of 4 different interventions (training on virtual reality, Armeo, an EEG-driven hand exoskeleton, and standard PT/OT).

Results: In a previous cross-sectional study, we proposed that an altered affected-arm muscle synergy may either be a merging or fractionation of unaffected-arm synergies (PNAS 2012). Here, we found that across all subjects, after rehab training, increase in the muscle-synergy similarity between the affected and unaffected arms (inter-arm synergy similarity, or ISS) correlated strongly with a reduction of synergy merging or fractionation in the affected arm. Interestingly, subjects with smaller ISS pre-rehab tended to show more increase in ISS after intervention. Post-rehab increase in ISS correlated with post-rehab increase in upper-limb Fugl-Meyer (FM) score only in severely impaired (FM<=35), but not in mild-to-moderately impaired (FM>35), survivors.

Conclusions: Overall, our results argue that the ISS has the potential to serve as a recovery biomarker with diagnostic and predictive values. Rehabilitative interventions may reduce impairment by restoring the compositions of muscle synergies in the affected arm, thus suggesting that the normative synergies could be the targets of new rehabilitative interventions.

S5 SYMPOSIUM: BIOMECHANICAL AND CLINICAL CHALLENGES IN THE SHOULDER FROM THE APPLIED PERSPECTIVE

S5.1 Scapula kinematics and gleno-humeral dynamic control in handball players with and without pain

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Background: Non-optimal scapula control during throwing has been suggested to increase risk of shoulder problems in throwing sports. Especially, lack of scapula posterior tilting and upward rotation may increase risk of impingement during the cocking phase of throwing, and inadequate muscle strength or non-optimal neuromuscular coordination have been suggested to contribute to problems during throwing. However, few studies have investigated the kinematics of scapula during throwing, and no previous studies have examined the effect of fatigue on scapula kinematics during throwing. This presentation will show kinematic data on scapula- and gleno-humeral joint control during throwing in male and female handball athletes, throwing with or without pain, and measured before and after a functional fatiguing protocol.

Methods: Data on different populations using the same protocol will be presented. Data from 8 healthy male handball players, 8 healthy female players and 8 female players, playing handball despite painful shoulders, was included. A custom designed marker model including a cluster for tracking the scapula was applied to the subject in a 3D motion analysis laboratory. After warm-up and initial model calibration, the 5 maximal throws were recorded. The functional fatiguing protocol consisted of alternating 5 maximal throws and 5 submaximal throws (80% of maximal velocity) with a 20 second pause between throws. After a total of 60 throws, 5 maximal throws were recorded. Fatigue was registered before and after using Borg's 11-point scale. 3D scapula positioning at the instant of maximal humeral external rotation was obtained as outcome parameters.

Results: The fatiguing protocol showed to increase ratings of fatigue and alter scapula kinematics in non-favourable way. All groups showed an increase in anterior tilt and reduced scapula upward rotation after the fatiguing period, and the female athletes also showed a reduction in scapula retraction. No differences in changes in scapula kinematics from pre to post fatigue were found between the healthy female group and the female athletes playing with pain.

Conclusions: Fatigue, caused by repetitive throwing, changed the scapula kinematics in a way that may place the shoulder in higher risk of impingement in both male and female athletes. However, athletes participating in handball despite shoulder pain were not more (or less) influenced by fatigue than healthy athletes. These results may indicate that preventive training should focus on enabling scapula muscles to control scapula in less anterior tilt and more upward rotation and more retraction during repetitive throwing.

S5.2 Ultrasound measurements of the Subacromial space and its usefulness in treatment of shoulder tendinopathy

Karen McCreesh
University of Limerick

BACKGROUND AND AIM: Impingement of the supraspinatus tendon due to acromial compression in a reduced subacromial space is a widely held pathomechanical theory for the development of shoulder pain. Current surgical approaches tend to focus on extrinsic causes of tendon impingement, directed at altering acromial shape, an approach which has come under increasing scrutiny. Consistent changes in the subacromial space tend to be seen only in the presence of substantial rotator cuff tears. This presentation will discuss the role of the subacromial space and its measurement in subacromial pain syndrome.

Methods: Reliability and validity investigations. Experimental study assessing the response of the subacromial space to fatigue.

Results: Ultrasound provides a reliable modality to measure the subacromial space, with excellent intra- and inter-rater reliability demonstrated. Construct validity was confirmed using a newly-developed ultrasound phantom of the shoulder. Short-term fatigue loading of the rotator cuff lead to a greater reduction in subacromial space in people with subacromial pain syndrome (11%) than controls (6%), as well as a slower return to baseline. This change was concurrent with a significant increase in thickness of the supraspinatus tendon, only in those with pain, leading to an increased subacromial occupation ratio, and potentially increased risk of tendon compression.

Conclusions: Valid and reliable measurements of the subacromial space can be taken using ultrasound imaging. Dynamic responses of the subacromial space to loading may be useful in determining level for progression of rotator cuff rehabilitation.

S5.3 Surface EMG activity of the upper trapezius before and after a single dry needling session in female office workers with trapezius myalgia

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Ghent University

Background and aim: Work-related neck pain is often related to myofascial dysfunction of the upper trapezius muscle. It has been demonstrated that a disturbed EMG activity may be associated with myofascial trigger points in the upper trapezius, both at rest and during functional upper limb tasks. Dry needling is a myofascial release technique, which has shown positive clinical treatment effects. However, the underlying mechanisms of action and the importance of eliciting local twitch responses remain unclear. The aim of this study was 1) to evaluate the effect of dry needling, compared to rest and compared to sham needling, on the surface EMG activity of the upper trapezius, following a fatiguing typing task; 2) to identify whether this effect is different in muscles with and without local twitch responses during dry needling, and 3) to investigate whether there are differences in this effect between the trigger point location and a distant muscle location.

Methods: Sixty-four male and female office workers with work-related trapezius myalgia were included. Subjects were asked to perform a typing task of 20 minutes. A first group of 24 female office workers received a resting pause after the first typing task, and a treatment with dry needling after the second typing task. A second group of 40 male and female office workers received a treatment with either dry needling or sham needling after the typing task. Resting surface EMG activity was measured before and after the typing task, and before and after the intervention. Dry needling and sham needling treatment were performed bilaterally at the trigger point location and in the second group also at a location 45 mm lateral of the myofascial trigger point.

Results: In the first group, the surface EMG activity increased after rest and after dry needling, compared to baseline, but this increase was significantly smaller 10 minutes after dry needling, compared to rest. These differences were independent whether local twitch responses were elicited or not. The results of the second group are still in progress since the study is not yet completed.

Conclusions: Several studies have shown an inability to relax the upper trapezius after completion of a functional upper limb task. It can be hypothesized that due to the physiological effects of dry needling, the muscle can recover more quickly, leading to a significantly smaller increase in surface EMG activity after dry needling, compared to rest. It is suggested that eliciting local twitch responses is associated with the degree of activity and irritability of the myofascial trigger point. This might explain the lack of differences between muscles with and without local twitch responses. Dry needling may lead to a faster muscle recovery after a fatiguing typing task, compared to rest. This effect is independent of the presence of local twitch responses during treatment.

S5.4 Marker-based scapula movement in clinical tests - methodological considerations and guidelines for practical application

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INTRODUCTION: Shoulder dysfunction may result from acute injury or other insults to the neuromuscular system ranging from stroke to neck pain. Clinical tests typically include isolated movements to assess range of motion, with or without pain, or simple reaching tasks like, e.g., Wolf Motor Function Test which is commonly used within Denmark. Various protocols for assessing scapula rhythm and function during such tests have been proposed. It was the aim of this paper to review current marker-based approaches and provide a set of guidelines about how to apply these in practice.

Methods: In our own laboratory, we developed a marker protocol and model in Visual 3D to quantify thorax, scapula, humerus and forearm movement in three dimensions. The model is based on the ISB recommendations for upper extremity coordinate systems. The reliability of the procedure in regard to discrete outcomes such as range of motion and start or maximum angles during specific movements was assessed. Further, a curve correlation method was applied to the time courses of joint and segment angles. Last, we have varied coordinate systems to better relate to anatomical angles which may be helpful for clinical purposes.

Results: The general results indicate that the most reliable discrete parameters were ranges of motion as opposed to start angles or absolute angles. The curve correlations revealed good reliability for scapula-thoracic movement but not for humero-scapular angles. The choice of coordinate systems aligned with a neutral reference trial showed substantially different angular variations compared to referring to the respective ISB coordinate systems.

Conclusion: We conclude that marker-based motion capture is a suitable tool for assessing scapula movement in clinical settings when using tasks which stay below a certain level of humerus elevation, which is in accordance with previous studies. We observed that the choice of coordinate system has a tremendous effect on the displayed curves which likely makes it very hard to compare between studies using different marker protocols and, in particular, with studies using other sensors which are fixed to different locations on the body. The most important general recommendation is that any study assessing shoulder kinematics requires a detailed and well-documented marker protocol and a detailed description of the model used for analysis.

S5.5 Assessment of hand-held and isokinetic measures of shoulder rotator strength

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BACKGROUND AND AIM: Shoulder pain is a common and incapacitating health problem among individuals with spinal cord injury (SCI). Manual wheelchair users with SCI seem to present with the most pervasive upper extremity problem of shoulder pain, because of the impact on mobility, transfers, activities of daily living and quality of life. Sport activities for SCI wheelchair athletes are known to increase shoulder loading even more, especially in tetraplegic individuals, due to extensive repetitive shoulder motions with limited rest periods. An underlying mechanism of shoulder pain could be reduced muscle strength in shoulder rotator muscles. The aim was to investigate the relationship between self-reported shoulder pain and rotational shoulder strength among tetraplegic wheelchair athletes. An additional aim was to investigate the concurrent validity of a handheld dynamometer (HHD) compared with isokinetic dynamometer (ID), in measurements of strength in shoulder rotators.

METHODS: In a cross-sectional design, data was collected among tetraplegic wheelchair athletes (n=12; Age 40.8±10.9) with 11 males. Shoulder pain measured by the self-reported Wheelchair Users Shoulder Pain Index-Performance Corrected (WUSPI-PC) corresponded to 17.8 (±18.9). Bilateral isometric and isokinetic muscle strength of the shoulder rotators (Internal, IR and External, ER rotation) were assessed using a HHD and Cybex ID at two velocities 60°/s and 180°/s. Body mass normalized (Nm/kg) isometric and isokinetic peak torque values were calculated. A simple linear regression analysis including residual analysis and Concordance Correlation Coefficients (CCC) was used for the analysis.

RESULTS: No significant relationships were seen between self-reported shoulder pain (WUSPI-PC) and all strength measures in relation to normalized peak torque values of rotational muscle strength or IR/ER torque ratios (p=0.07-0.40). Of notice, all the non-significant associations did consistently demonstrate negative beta values (ß -0.004 - -0.009) explaining between 2.6%-28.8% of the variation in shoulder joint torque. Concurrent validity of HHD compared with ID for all normalized torque values had satisfactory CCC (.> 0.75). CCC point estimates with 95% CI for IR and ER at 60°/s were 0.94 (0.83-0.98) and 0.94 (0.84-0.98), respectively and at 180°/s for IR 0.76 (0.53-0.88) and for ER 180°/s 0.81 (0.60-0.92), respectively.

CONCLUSIONS: Despite the statistically non-significant relationships between shoulder pain and strength measures, an overall negative relationship was found, presumably indicating that shoulder pain to some extent is negatively associated with muscle strength. However, this needs to be confirmed in a larger population with more pain variability and sufficient power. The satisfactory validity of the HHD compared with gold standard method of ID, indicates that the hand held measurement seems to be a relevant method to assess shoulder joint torque in tetraplegic individuals in a sport or clinical setting. The overall results of this pilot study give reasons to further investigate the relationship between shoulder pain and strength assessment. More insight into this area, in addition to the relation to shoulder muscle activity may lead to better treatment and prevention strategies.

O8 KNEE BIOMECHANICS AND REHABILITATION II

O8.1 Kinematic analysis of the talocrural and subtalar joint after lateral compartments ligaments resection: can motion changes be detected by 4D-CT acquisition?

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BACKGROUND AND AIM: Four-dimensional computed tomography (4D-CT) is a novel imaging method for real-time motion analysis with the potential to detect joint related musculoskeletal pathologies. However, its ability to detect small changes due to ligament insufficiency is still under investigation. The purpose of this study was to investigate the capability of dynamic CT acquisition to detect kinematic changes induced by sequential sectioning of lateral ankle ligaments.

METHODS: Dynamic CT acquisitions were performed on one fresh frozen ankle specimen during foot inversion. A 256-slice GE Revolution CT Scanner (80 kV, 25 mA, gantry rotation time 0.28 s, z-axis coverage 120 mm, scanning time 3.92 s) was used. The tibia was fixed on a custom-made device and the ankle joint was moved at a pace of 25 cycles/minute. After four separate dynamic acquisitions with the ankle undamaged, three scenarios were considered for sequential ligament sectioning: 1) section of the the Anterior Talo-Fibular Ligament, 2) section of the Calcaneo-Fibular Ligament and 3) section the Posterior Talo-Fibular Ligament. Four distinct dynamic CT acquisitions were repeated for each scenario. Using mutual information as the similarity metric, the talus and the tibia of the dynamic sequences were rigidly registered to a reference image dataset of the foot at rest and transformation matrixes were derived. The technical frame (XYZ) of the CT scanner was used to described the 3D-motion. Joint kinematics of the talocrural joint and subtalar joint were defined as Cardan angles rotation calculated based on the composition sequence ZYX and ZXY respectively.

RESULTS: Maximum detectable differences in bone rotation of the talocrural joint were 6.07˚, 5.46˚ and 9.83˚ between intact vs first cut, intact vs second cut and intact vs third cut respectively around the X-axis (flexion/extension), 5.12˚, 5.47˚ and 10.01˚ around the Y-axis (pro-supination), and 4.88˚, 5.47˚ and 6.93˚ around the Z-axis (abduction/adduction) (Figure 1). Regarding the subtalar joint, a maximal detectable difference of bone rotation was 0.37˚, 0.81˚ and 4.09˚ around the X-axis, 2.49˚, 3.28˚ and 7.82˚ around the Y-axis, and 1.33˚, 1.87˚ and 2.09˚ around the Z-axis. Each acquisition required a radiation dose (CTDIvol) of 1.9mGy.

CONCLUSIONS: We demonstrated that sequential sectioning of the lateral ankle ligaments progressively increased the angular motion in both the talocrural and subtalar joint, especially after the last ligament was sectioned. As such, this study demonstrated that minimal kinematics changes due to ligaments failure can be demonstrated with 4D-CT. However, it also showed that the amount of kinematic changes is related to the amount of ligament damage. 4D-CT allows detailed acquisition in vivo situation and highlight the possibility of adopting such method to investigate joint kinematics when different pathological conditions are present with a very small radiation exposure for the patient.

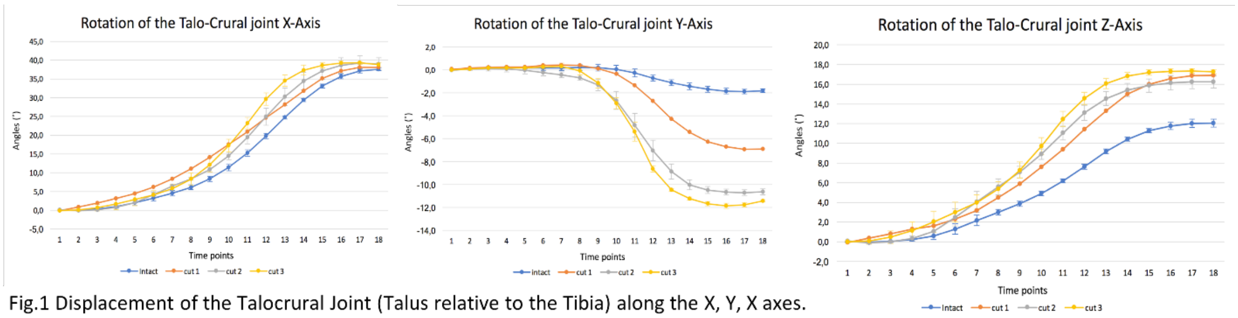

Fig.1 Displacement of the Talocrural Joint (Talus relative to the Tibia) along the X, Y, X axes.

O8.2 Differential quadriceps muscle activation after a femoral nerve blockade prior an anterior cruciate ligament reconstrucion

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Background: After an anterior cruciate ligament (ACL), an ACL reconstruction (ACLR) is normally indicated to restore static stability, followed by a rehabilitation process that may last several months. However, quadriceps weakness can be observed in the early stages of rehabilitation and even after medical discharge. Central nervous system (CNS) impairments, pre-surgery muscle atrophy and quadriceps muscle activation deficits have been marked as factors that affects quadriceps strength in the different rehabilitations stages. It has been hypostasized that femoral nerve blockades prior to an ACLR may affect muscle function. This nerve blockade not only produces an analgesic effect but also a motor nerve blockade, resulting in a temporal impairing of quadriceps muscle function. Thus, immediate post-operative rehabilitation may be impaired by this blockade.

Aim: To describe the differential effect of two commonly used LAs concentrations, over quadriceps force and myoelectrical activity of vastus medialis (VM), vastus lateralis (VL) and rectus femoris (RL), before and after a FNB in subjects underweening an ACLR

Methods: Twenty subjects were recruited for this study. The FNB was performed by an anesthetist, approximately 45 to 60 minutes before surgery. Two different anesthetic doses were randomly used to produce an analgesic effect. Dose 1 (Group 1) consist in 15 ml of bupivacaine 0,375% with epinephrine 5µg/ml and dose 2 (Group 2) consist in 15 ml of bupivacaine 0,25% with epinephrine 5µg/ml. Quadriceps maximal voluntary isometric contraction (MVIC) and quadriceps myoelectrical activity assessed by surface electromyography (sEMG) were performed simultaneously, before and 30 minutes after the FNB. Quadriceps MVIC was evaluated using as S beam load cell attached by a chain to a modified hospital gurney. sEMG sensors were placed over VM, VL and RF muscles bellis according to SENIAM recommendations. sEMG of VM, VL and RF were fully rectified by the root-mean-squared (RMS) method across a 125 ms moving window with a 6.25 ms window overlap. Then, the highest amplitude of the three maximal contractions were averaged.

Results: Quadriceps MVIC of group 1 showed a significant decrease of 22.2 ± 16.6% after the FNB ($p = 0.049$) MVIC of groups 2 results in a substantial decrease of 13.8 ± 9.9% after the FNB ($p = 0.019$). After the FNB was applied, both groups showed a significant decrease in the electromyographic activity of VM, VL and RF. The most significant decreased was in RF activity for both groups.

Conclusion: Both doses produce a measurable decreased in quadriceps MVIC and sEMG activity, affecting quadriceps function in the immediate rehabilitation. RF muscle was the most affected, suggesting that initial rehabilitation must uses exercises that favors RF training

O8.3 Lower limb kinematics and kinetics of a novel one-leg double-hop test involving unanticipated/anticipated diagonal hops in individuals with unilateral anterior cruciate ligament reconstruction

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BACKGROUND AND AIM: Anterior cruciate ligament (ACL) injury is a debilitating injury especially for athletes. Around 70% of ACL injuries occur in noncontact sports situations, probably due to aberrant lower limb biomechanics, with the knee abducted and internally rotated, during land-and-cut maneuvers performed under unanticipated conditions. A one-leg lateral diagonal hop might emulate the mechanics of a cross-over cut and is more difficult to perform than a simple forward hop. Therefore, we designed a double-hop test (a forward hop followed by a lateral diagonal hop [45°]) performed under unanticipated and anticipated conditions. We compared the effects of anticipation between legs on lower limb biomechanics of the novel test in individuals with a unilateral ACL reconstruction (ACLR). We expected larger joint angles and moments during unanticipated than anticipated trials for ACLR and uninjured legs.

Methods: Twenty-three individuals (age: 24.0±4.2 years, Tegner activity level: median [range], 7 [4-9], 18 females) with a unilateral ACLR (37.3±34.5 months post-surgery) performed 3 successful unanticipated (ULDH) and anticipated lateral diagonal hops (LDH). Participants performed medial/lateral diagonal hops (only lateral was analyzed) based on a visual cue randomly indicating hop direction presented ?300 ms and ?2 s, respectively, prior to the land-and-cut maneuver for ULDH and LDH. An 8-camera 3-D motion capture system and 2 force plates were used. Hip, knee, and ankle peak angles and external joint moments during the deceleration phase (initial foot contact to peak knee flexion) of the land-and-cut maneuver were calculated. Multiple 2*2 (leg*condition) repeated measures ANOVAs were used ($p < 0.05$).

Results: Participants showed a pattern of hip flexion, adduction, and internal rotation, knee flexion, adduction, and external rotation, and ankle/foot plantar flexion, pronation and external rotation across conditions and legs. There was no interaction between leg and condition for any variable. Significant main effects were observed for condition, irrespective of leg, for most peak angles and moments in all 3 planes. Most angles and certain moments of the hip, knee, and ankle were higher during ULDH than LDH. Some significant main effects were found for leg: hip flexion and adduction angles, hip flexion and internal rotation moments were higher, and knee flexion moments were lower for the ACLR leg than the uninjured leg, irrespective of condition.

Conclusions: Nearly all peak angles and certain peak moments were higher in ULDH than LDH for ACLR and uninjured legs. Low peak knee abduction and internal rotation angles/moments observed during these tasks indicate less vulnerability of the knee to ACL injury risk. However, the relatively large hip and knee movements in all 3 planes noticed during ULDH might particularly challenge dynamic knee control. Our test may safely be used to evaluate knee function or rehabilitation of individuals with ACLR.

O8.4 Does the Loss of Vastus Medialis Alter Patellofemoral Joint Contact Pressures In Vivo?

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BACKGROUND AND AIM: Although patellofemoral pain (PFP) is recognized as one of the most frequent musculoskeletal disorders, its etiology remains uncertain [1, 2]. One generally accepted speculation is that weakness of the vastus medialis (VM) in the quadriceps group causes PFP [3]. It is assumed that the weakened VM produces altered patellar tracking and changes in patellofemoral joint (PFJ) contact pressure distributions, which result in PFP [4]. However, there is no direct evidence supporting this assumption. Therefore, the purpose of this study was to determine if VM weakness changes contact pressure distributions in the PFJ.

Methods: Six skeletally mature New Zealand White rabbits were used. Three custom-built nerve cuff electrodes were surgically implanted on the individual nerve branches of the vastus lateralis (VL), VM, and rectus femoris (RF) to allow for individually controlled activation of these muscles. Following surgery, rabbits were held in a stereotaxic frame using bilateral bone pins inserted into the pelvis and femoral condyles. A tibial restraining bar was used to prevent knee extension and to measure knee extensor torques. Bilateral retinacular incisions were made to allow for insertion of a pressure sensitive film into the PFJ. Knee extensor torques and PFJ contact pressures were measured when stimulating all three muscles simultaneously (ALL) and when stimulating VL and RF only (VLRF), thereby simulating VM loss. All experimental procedures were approved by the Animal Ethics Review Committee of the University of Calgary. Pressure stains were collected from the pressure sensitive film, and peak PFJ contact pressures and contact areas were determined using a custom-written analysis program (MATLAB). PFJ contact pressure distributions for the ALL and VLRF conditions were compared for identical knee joint angles (90°) and the same (±5 %) knee extensor torque. Paired t-test was used to compare peak pressures and joint contact areas between the two conditions. The level of significance was set at $p < 0.05$.

Results & DISCUSSIONS: Peak PFJ contact pressure was greater and contact area was smaller for the VLRF compared to the ALL condition (Table 1). We concluded from this result that a weak VM results in greater PFJ peak and average pressures, thereby potentially causing PFP often associated with strength imbalances of the knee extensor muscles.

Conclusions: VM weakness caused an increase in peak and average pressures in the PFJ, which may lead to PFP.

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	ALL	VLRF	*p* - value
Peak pressure (MPa)	28.9 16.2	34.9 18.2	< .001
Contact area (mm^2)	12.1 4.9	11.6 4.7	0.02

Table 1. Comparisons of peak pressure and contact area between experimen-tal c alues are given as mean 1 standard de - taneous s , VM, and RF; VLRF = simultaneous s VL and RF while VM was not s ed to simulate experimentally extreme VM weakness). Note that comparisons of PFJ mechanics between the ALL and VLRF c or an iden al knee angle and the same total knee extensor forces.

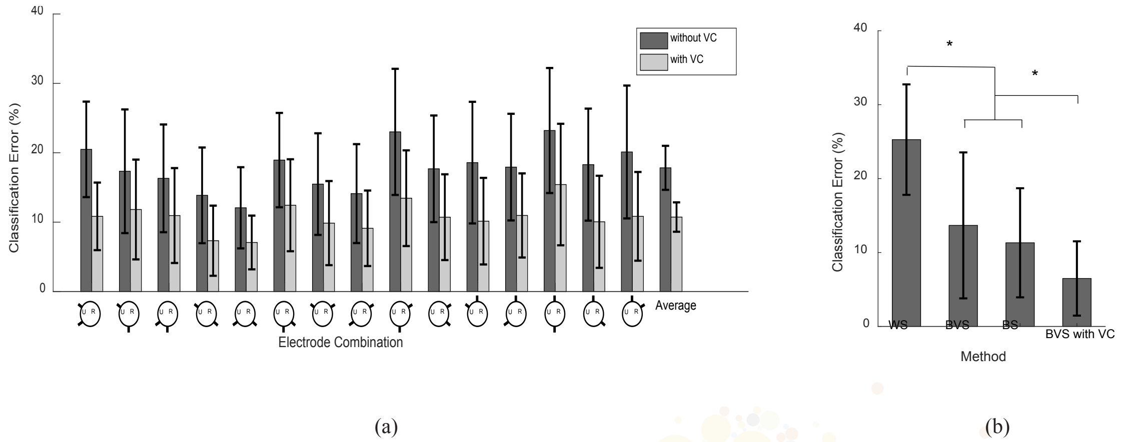

Fig. 1. Error rates of (a) two algorithms (without and with VC) with different electrode positions, and (b) four methods comparison on seven movements, hand close, hand open, wrist flexion, wrist extension, supination, pronation and rest. The tick label of horizontal axis in (a) displayed the positions of two electrodes. The circle represents the cross-sectional view of the arm. The letter U and R indicate the position of ulnar and radius, respectively. The black dot represents the positions of the two electrodes used. The last column of each figure represents the error rates averaged across all the electrode combinations. The tick label of horizontal axis in (b) represents the classification method with electrode subset WS without VC, with electrode subset BVS without VC, with electrode subset BS without VC, and with electrode subset BVS with VC. Star denotes the significant difference between two compared methods ($p < 0.05$).All the results are averaged across the subjects.

O8.5 3D Hip and knee kinematics during single and triple hop tests after ACL reconstruction as measured with inertial measurement units

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Background and Aim: After an Anterior Cruciate Ligament reconstruction (ACLR), patients often suffer from limited knee stability that negatively influences return to play. Hop testing is a common functional test to determine return to play status. Due to the difficulty in capturing knee and hip kinematics over a large area while hopping little is known of differences in knee and hip kinematics that may persist that are related to knee stability. Advancements in inertial sensor technology allow for assessment of hip and knee kinematics outside the laboratory setting and could provide significant insights into how these functional tests are performed in relation to return to play. The aim is therefore to investigate hip and knee kinematics in ACLR patients and healthy controls in the sagittal and frontal plane during hop tests (i.e. single leg and triple hop for distance), using inertial magnetic measurement units (IMUs).

Methods: As part of a larger study in which hop tests are being evaluated, 5 ACLR patients (2 M, 3 F, 20.4 ± 2.1 yrs, 164.2 ± 10.7 cm, 69.1 ± 23.5 kg) one year post reconstruction, and 10 healthy controls (7 M, 3 F, 21.8 ± 2.0 yrs, 178.3± 10.2 cm, 73.5± 14.3 kg) performed a single leg hop and a triple hop for distance with the reconstructed or dominant leg. They were equipped with 8 IMUs (Xsens, sampling frequency 100 Hz) that were placed at the feet, tibia, upper legs, sacrum and sternum. Sagittal and frontal plane hip and knee angles (flexion, abduction) at initial contact (IC) were calculated. Independent Mann-Whitney U-tests were used to statistically compare the data.

Results: Significant differences ($p<0.05$) in knee and hip flexion and knee abduction were observed at IC for the single leg hop and triple hop between groups (table 1).

Conclusions: Subjects who have had an ACLR employ landing strategy of less hip and knee flexion and abduction when performing a single leg and triple hop as compared to the mechanics of healthy control subjects. This results in a stiffer landing strategy that may predispose them to secondary injuries if not fully addressed. Objectifying these hop tests using inertial sensors provides additional information on knee and hip kinematics over standard outcome measures.

Supported by a grant from the Dutch Fulbright Centre.

Table 1: Knee and hip mechanics (±SD) during single leg and each landing from triple hop at IC; an asterisk denotes a statistical significant difference at p<0.05

		Single leg hop			Triple Hop								
		IC			IC 1			IC 2			IC 3		
		ACLR		Control	ACLR		Control	ACLR		Control	ACLR		Control
Knee	Flexion	10.1(9.9)	*	20.2(7.4)	16.7(9.3)	*	34.1(14.1)	13.7(9.0)	*	32.7(17.4)	11.0(6.6)	*	22.9(20.7*)
	Abduction	0.2(3.5)	*	4.0(3.3)	0.9(4.0)		6.1(6.1)	0.8(3.4)		5.0(5.1)	-0.3(5.8)		3.5(7.0)
Hip	Flexion	29.3(9.1)	*	44.1(9.5)	33.3(4.8)	*	42.2(8.5)	32.1(5.5)	*	43.4(5.8)	28.8(8.1)	*	40.5(12.9)
	Abduction	7.8(6.0)		6.0(7.7)	0.8(5.8)		2.4(5.5)	1.5(2.9)		0.5(4.5)	7.1(7.7)		10.0(6.2)

O8.6 Thirty minutes of treadmill walking significantly alters knee muscle activation and joint biomechanics in asymptomatic individuals and people with moderate knee osteoarthritis

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Background and Aim: Muscle activation and joint mechanics during walking have been used to understand the implications of conservative interventions on knee osteoarthritis (OA) joint function. To date, these studies have examined a brief bout of walking (3-10 trials, completed in less than five minutes). The study purpose was to examine whether muscle activation patterns and knee biomechanics change as asymptomatic individuals and people with moderate knee OA walk for at least 30 minutes.

Methods: 46 individuals (Moderate knee OA (n=24), Asymptomatic (n=22)) participated after giving informed consent. Using standardized procedures, skin surface electrodes (Ag/AgCl) were placed in a bipolar configuration over the lateral and medial gastrocnemius and hamstrings, vastus lateralis, medialis and rectus femoris. Retro-reflective markers were placed on lower limbs. A dual-belt instrumented treadmill (MotekForcelink) was set to over-ground walking speed and recorded ground reaction forces and moments at 2000Hz. Electromyograms (EMG) were recorded at 2000Hz (Bortec Inc.). Skin surface marker motion was captured at 100Hz (Qualisys). Participants walked barefoot for at least 30 minutes with 10s recordings completed at 6 minutes and after 30 minutes. Between minute 6 and 30, a random series of small medial/lateral walk way surface perturbations were delivered. EMG were band-pass filtered (10-500Hz), corrected for subject bias, full wave rectified, low-pass filtered (6Hz) and amplitude normalized to maximal voluntary isometric contractions. Knee joint angles were calculated. Inverse dynamics was used to calculate sagittal and frontal plane knee moments. Discrete measures (i.e. peak KAM) were extracted from biomechanical variables and Principal Component Analysis was used to evaluate EMG waveform features. Analysis of Variance models (alpha=0.05) were used for statistical hypothesis testing.

Results: In both groups, knee range of motion from initial contact to peak stance flexion was greater, peak external flexion moment greater, KAM impulse greater and peak KAM greater after at least 30 minutes of walking compared to 6 minutes ($p<0.05$). Quadriceps, hamstrings and gastrocnemius activation levels were reduced after 30 minutes of walking (PP1scores-$p<0.001$) with more dynamic and less sustained activation (Quads-PP3scores, Hams-PP2scores, Gastrocnemius-PP3scores). Effect sizes (Cohens d) were low (d~0.2) with exception of increased peak KAM (d=0.35) and reduced overall hamstring activation (PP1scores)(d=0.32). No group by time interactions were found ($p>0.05$).

Conclusions: Walking for 30 minutes significantly increases peak KAM and flexion moments while reducing overall knee muscle activation amplitudes and altering temporal patterns towards a more dynamic response with less sustained activation. Effect sizes were moderate for some variables suggesting practical significance. Whether 30 minutes of walking changes the knee loading requires further work.

O9 EMG MODELING & PROCESSING I - MODELING

O9.1 Mathematical Analysis of a Model of Intracellular Action Potential Generation

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BACKGROUND AND AIM: Mathematical models of surface EMG usually assume some model of intracellular action potential generation. Various models of IAP generation have been proposed for this purpose, one of which is the well-known model of Farina and Merletti (2001). This model has been successfully employed in a number of applications, however, it may be difficult to analyze mathematically and interpret correctly. In particular, the model contains derivatives that are not defined in the classical sense and may only be understood in the sense of distributions, and moreover, the physiological meaning of some of the model components may not be obvious. The aim of the present contribution is to derive an alternative, yet equivalent, formulation of the model of Farina and Merletti that is easier to analyze and interpret physiologically.

Methods: An alternative equivalent formulation of the original model is derived rigorously. The novel formulation does not include derivatives of distributions and is hence easier to analyze mathematically. Subsequently, using the reformulated model, a proof is provided that in this model, no fiber represents a net current source or sink at any point in time.

Results: The proposed alternative formulation of the IAP generation model facilitates physiological interpretation of the model. The derived property of zero current balance further proves the model's physiological validity, as it is in accordance both with the assumed quasi-stationarity of the generated electrical fields, as well as with the predictions of the Hodgkin-Huxley equations.

Conclusions: The proposed alternative formulation of a well-known model for IAP generation facilitates physiological interpretation and mathematical analysis of the model. The model's mathematical properties further support its physiological validity.

O9.2 Influence of index flexion and abduction on the EMG signals recorded from the first dorsal interosseous muscle: an electrophysiological model based on diffusion tensor imaging

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A realistic subject-specific electromyography (EMG) model of the first dorsal interosseous (FDI) muscle of the hand is presented. The model, which includes detailed muscle fibre architecture obtained using diffusion tensor imaging (DTI), is used to explore the effect of changes in fibre curvature and direction during muscle activation on simulated motor unit action potentials. EMG signals recorded from the FDI have been widely utilised to understand motor control and muscle activation mechanisms under both normal and pathological conditions. In addition to the motor units firing times, the surface EMG signal is influenced by the individual motor unit action potentials waveforms which depend on the electrical and geometrical properties of the surrounding tissues. Subject-specific models which can incorporate details of the individual subject anatomy and muscle fibre architecture can thus provide insight into how these factors influence the EMG signal recorded in vivo.
Magnetic resonance imaging (MRI) and diffusion data were acquired for a single subject positioned prone in a Philips 3T Achieva scanner. The subject's dominant hand was positioned prone on a purpose-built rig in a 16-element transmit/receive radiofrequency knee coil. MRI data for the hand at rest were segmented into bone, muscle, fat, and skin tissue and a finite element model was constructed with different dielectric properties associated with each tissue. Immediately after the anatomical MRI and using the same experimental arrangement, diffusion data were acquired under three different conditions: hand at rest, index finger flexed, and index finger abducted. Based on the diffusion data, a deterministic fibre tracking approach, after motion and eddy current correction, was employed to estimate FDI muscle fibre curvature and direction for the different muscle states. In the finite element model, the estimated fibre tracts were then used to account for muscle anisotropy, through the attribution of an anisotropic electrical conductivity to the FDI, and to determine the propagation direction of muscle fibre action potentials. EMG signals detected at an array of electrodes located on the skin surface directly above the FDI were then simulated. Motor unit action potentials (MUAPs) were simulated as the summation of single fibre action potentials detected during propagation of intracellular action potentials along the identified muscle fibre trajectories. A qualitative validation of the proposed approach was obtained through the comparison between action potentials simulated using the subject-specific model were then compared with MUAPs experimentally recorded from the same subject. The validated approach was then used to examine how the changes in fibre direction and curvature with FDI activation influence the characteristics of the motor unit action potential waveforms of the recorded electromyograms.

O9.3 Influence of the conduction properties of muscle tissue on surface motor unit action potentials

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BACKGROUND AND AIM: Many mathematical models of the surface electromyographic (sEMG) signal have been described in the research literature to shed light on the mechanisms of muscle contraction in health and disease [1-2]. A fundamental aspect of these models is the description of how motor unit action potentials (MUAPs) generated by the active muscle fibers propagate through the muscle tissue and are detected from the surface of the skin. Traditional models typically describe muscle tissue as an anisotropic layer with space-invariant or smoothly varying electrical properties [3]. However, muscle tissue is an inhomogeneous material, composed of elements with different electrical properties, such as blood vessels, intramuscular fat, and muscle fibers. The influence of this inhomogeneity on MUAP propagation has not yet been fully investigated.

Methods: We developed a finite element model of the Biceps Brachii muscle to identify differences in MUAP shapes detected from the surface of the skin when muscle tissue is described as either an anisotropic layer or an inhomogeneous layer containing elements with different electrical properties, i.e. blood vessels, intramuscular fat, and muscle fibers. Characteristic features of MUAP shape obtained using both the anisotropic and the inhomogeous description of muscle tissue were compared to those of empirical MUAPs extracted from real sEMG signals recorded during voluntary muscle contractions [4].

Results: Results showed that the inhomogeneous description of muscle tissue results in greater complexity of MUAP shapes compared to the anistropic description, which results in a greater number of phases and turns. Furthermore, MUAPs in the inhomogeneous description present a wide variability in shapes within the MUAP pool, due to the position in the muscle. MUAP shapes obtained using the inhomogenous description of muscle tissue better replicated the physiological complexity of real MUAPs.

Conclusions: This finding suggests that an inhomogeneous description of the electrical properties of muscle tissue more closely replicates the physiological complexity of MUAP propagation.

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O9.4 The specific impedance of the intra-fascicle environment obtained via nerve fibre models

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BACKGROUND AND AIM: Peripheral nerve interfaces offer a means to control neural prosthetics. The performance of nerve-cuff based neural electrical impedance tomography and functional electrical stimulation is aided by the use of finite element analysis to predict current density distribution of injected signals. However, the electrical impedance of intra-fascicle environment (IFE) in the peripheral nerve is not defined in literature. Instead, researchers commonly use values obtained from the dorsal column of cat [1] which differs in cytology from peripheral nerve. This study obtained estimates of the impedance of the IFE of mammalian peripheral nerves in the active and inactive states using equivalent electrical circuit models of myelinated and unmyelinated fibres.

METHODS: The transverse impedance of an unmyelinated fibre was calculated using theory derived from long, thin-walled cylinders in a uniform transverse field. We applied this theory to myelinated fibres by first solving for the axon in periaxonal space, then nesting the solution inside a myelin sheath and extracellular space and solving again. The longitudinal impedance of an unmyelinated fibre was calculated using the single-cable theory model presented in [2]. We applied this to myelinated fibres by combining the node of Ranvier and myelin sheath into a single resistor and capacitor in parallel and removing the periaxonal space. Impedance estimates were combined with fibre diameter distribution of the rat sciatic nerve and an interstitial tissue conductivity of 0.1 S/m, to generate an estimate for impedance of the IFE.

RESULTS: The transverse resistivity of the IFE in both active and inactive states was 10.6 Ωm below 5.5e7 Hz reducing to 3.7 Ωm above 8.0e10 Hz. The longitudinal resistivity of the IFE was 3.5 Ωm below 100 Hz dropping to 2.0e5 Ωm above 2e5 Hz in the inactive state, and 2.14 Ωm below 10e4 Hz dropping to 2.0e5 Ohm.m above 2e5 Hz in the active state. It was not possible to improve agreement between estimated resistivity values of the IFE at 1 kHz and in-vivo data from dorsal column of cat [1] by modifying the interstitial conductivity. The predicted fraction change in IFE impedance between active and inactive states are in agreement with in-vivo data presented in [3] when passive tissues are included. Initial data gathered on ex-vivo tissue sample with an uncalibrated system showed the frequency at which the impedance drop begins was lower than expected but otherwise in reasonable agreement with the model.

CONCLUSION: This model suggests that the differences in cytology between the dorsal column and peripheral nerve produce significantly different tissue impedances. In-vivo measurements of IFE impedance should be obtained to verify this.

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O9.5 Modeling the synaptic input to motor neurons in spastic muscles

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BACKGROUND AND AIM Spasticity is a common consequence in patients with brain lesions. However, the underlying mechanisms responsible for the changes in the muscular activation after lesion still remain unclear. High spatial resolution electromyography (HSR-EMG) has shown, that patients suffering from spasticity after stroke have a typically changed input to motor neurons compared to healthy subjects. Particularly discharge rate is decreased and less variable compared to healthy subjects. Farina et al. have hypothesized that the input to the motor neuron pool consist of a common synaptic input common to all motor neurons and an independent input, which is specific for each motor neuron. This study aims to investigate, whether the characteristic changes in the HSR-EMG signal related to spasticity can be simulated by changing either the common input or the independent input to the motor neuron pool.

Methods: 10 healthy subjects and 10 patients suffering from spasticity after stroke take part in the study. HSR-EMG has been recorded during maximum voluntary contraction of the m. abductor pollicis. Altogether 7 parameters have been calculated from the HSR-EMG signals. The values of each parameter are significantly different in patients compared to healthy subjects. A muscle model has been developed, which allows the simulation of a HSR-EMG signal. Excitation of the motor neuros followed the common input and the independent input concept of Farina et al. Model parameter have been chosen in such an way, that no difference in parameter values derived from simulated and experimentally gained HSR-EMG signals of healthy subjects exist. Based on the model representing the healthy muscle and the normal excitation of the motor neurons, common input and independent input to the motor neuron pool have been changed systematically, in order to get best agreement with the parameter values gained from the HSR-EMG signals of patients suffering from spasticity.

Results: Best agreement between the parameter values of simulated and experimentally gained HSR-EMG signals have been found when the independent input to the motor neuron pool is distinctly reduced. In none of the parameters a significant difference between the parameter values of simulated and experimentally gained HSR-EMG signals occurs when reducing the independent input closely to zero. No similar consistency between simulated signals and experimentally signals could be achieved when varying the common input, the common noise or any other muscle model parameters.

Conclusion: The simulation results suggest that the brain lesion influences mainly the individual input to the motor neuron pool while the common input remain unchanged. On the other hand, the correct modeling of the synaptic input to motor neurons in spastic muscles needs the assumption of an individual input to the motor neurons. This is why other attempts in modeling the synaptic input fail when regarding spastic excitation of the muscle.

O9.6 Modelling voluntary contraction of knee extensors using a motor unit recruitment model

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BACKGROUND AND AIM: Skeletal muscles provide the means for humans to move voluntarily. In this work, we model the force output of vastus lateralis (VL) muscle by statistically generating individual motor unit mechanical properties and individual firings. The motor unit recruitment model in [2] is altered such that the voluntary contraction capabilities of the vastus lateralis (VL) muscle can be reconstructed.

Methods: Recruitment and twitch properties of individual motor units are essential for realistic estimation of the strength of any skeletal muscle. However, not all the properties (e.g. conduction velocity, twitch force) of each motor unit controlling a muscle can be determined experimentally. To account for the lack of experimental data, the motor unit pool is modelled based on the available information on the order of magnitude of the conduction velocity for the VL muscle, distribution of the motor unit types, its force output during an MVC and the size principle. The correlation of the conduction velocity with the recruitment threshold for each motor unit, thus the force level, is also included in the model [3].

Results: Different than former models on the matter (see [1]), our model describes the full recruitment of the motor units in a VL muscle. Scenarios for the distribution of the motor unit properties in the VL motor unit pool are tested against the target force during a maximum voluntary contraction.

Acknowledgement: This study is funded by the German Science Foundation (DFG) within the Cluster of Excellence in Simulation Technology (EXC 310/1) at the University of Stuttgart.

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O10 MOTOR UNITS

O10.1 A novel insertion technique for intramuscular measurement of EMG activity of the deep intrinsic foot muscles during walking

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BACKGROUND AND AIM: The intrinsic foot muscles are proposed to support the foot's complex function during gait. Although studies have used intramuscular EMG to record activity of superficial intrinsic foot muscles during gait, understanding of deep intrinsic foot muscle fuction has been limited due to challenges accessing these muscles for intramuscular EMG recording. This study aimed to: (i) develop an insertion technique for intramuscular EMG recording of the adductor hallucis (AddH) and first dorsal interosseous (FDI) muscles in humans; (ii) demonstrate the feasibility and quality of recording EMG data of AddH and FDI during shod walking; (iii) report side effects of the method; and (iv) describe patterns of intrinsic and extrinsic foot muscle activity during walking.

Methods: Eight pain-free individuals (5 males; mean[SD] age 32[8] years; BMI 23.5[6.3] kg/m2) participated. Intramuscular electrodes for AddH and FDI were inserted through the dorsum of the foot, between the first and second metatarsals. Real-time ultrasound imaging guided electrode placement in AddH and FDI, with the ultrasound probe positioned on the plantar surface of the foot. Intramuscular electrodes were also inserted in the abductor hallucis (AbdH), tibialis posterior (TP), flexor digitorim longus (FDL) and peroneus longus (PL) using reported methods. Participants performed six trials of overground walking wearing standardised shoes, and reported any discomfort associated with the intramuscular electrodes during walking on a numerical rating scale (0-10). EMG data were sampled at 2000Hz, and filtered (band-pass, 8th order Butterworth, 70-1000Hz). Data were visually inspected for artifacts before extracting EMG envelopes.

Results: Clear recordings were obtained from intrinsic and extrinsic muscles. Power analysis indicated that movement artifacts commonly observed during gait were eliminated by filtering. Discomfort for AddH/FDI electrodes was 1.3[1.6] (range 0-4), similar to other insertion sites. Distinct patterns of activation were observed among foot muscles (Figure 1). Intrinsic foot muscle activity (AddH, FDI, AbdH) demonstrated two peaks: (i) around heel strike; and (ii) late stance/toe off in the transition to swing phase. AddH and FDI peak activity was greater at later stance, in contrast to AbdH (greater peak at heel strike). Extrinsic foot muscle (TP, FDL, PL) activity peaked during the propulsive phase of gait (after foot flat), in accordance with previous findings. The mean correlation between individual participants' EMG and the group average was >0.7, demonstrating consistent patterns across participants.

Conclusions: This study demonstrates the feasibility of recording intramuscular EMG from the deep intrinsic foot muscles, with minimal discomfort. Observed EMG patterns suggest that activity of the deep intrinsic foot muscles may be distinct from the superficial intrinsic muscles.

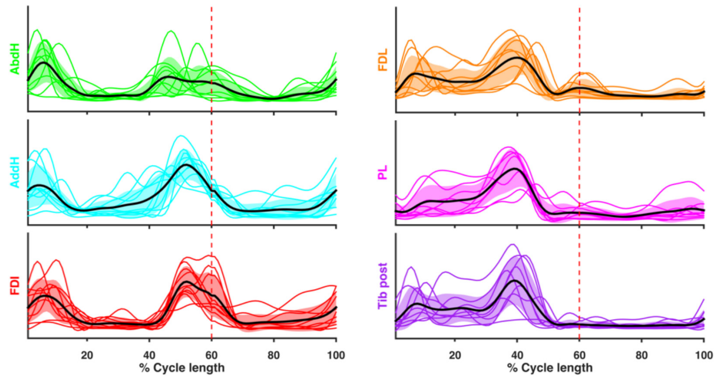

Figure 1. Group mean EMG activity (black line), and individual participant EMG activity (individual coloured lines) for each muscle, across one stride cycle (EMG amplitude normalised to peak activity across trials). Shaded regions denote one standard deviation about the mean. Red dashed line denotes toe off.

O10.2 Influence of muscle length on motor unit discharge rates in the tibialis anterior muscle

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University of Brescia

BACKGROUND AND AIM: Single muscle fibre output force is larger when the pre-activation sarcomere length is encompassed between 2.00 and 2.25 μm. Therefore, the muscle length at which the largest number of fibres are closer at their most efficient length range will provide the largest mechanical output. Muscle output force is controlled by the central nervous system (CNS) modulating the number and the discharge rate of the active motor units (MU). In the literature, the muscle length influence on the CNS adopted strategy for tension control is not well outlined even if some evidences, based on intramuscular EMG, suggest that MU firing rate may be larger the shorter the muscle is. Using a non-invasive technique as the high-density surface EMG (HD-EMG), this work was aimed to provide data about the relationship between the muscle length, the mechanical output and the MU firing statistics at three different muscle lengths during submaximal static contraction during voluntary action.

METHODS: Six male subjects (age 19-30) with no neuromuscular diseases were studied. The investigated muscle was the tibialis anterior (TA). The HDSEMG and the torque signal were detected during static voluntary contraction at three ankle joint angles: 90°, 110° (ankle neutral angle) and 130° and at two submaximal static efforts: 10 and 20% of the maximal voluntary contraction (MVC). At each angle, the TA MVC was estimated and a 40 s sustained contraction at 10 and 20% MVC was performed. HDSEMG was detected by 64 electrodes on the TA surface. The HDSEMG was analyzed using a "blind source separation" algorithm (Negro et al. 2016), after decomposition the single motor unit firing pattern (MUFP) was obtained.

RESULTS: The highest MVC was recorded at 110° in all subjects. At 90°, 110° and 130°, the group average firing of the identified MUs were 12.5±1.2, 10.9±1.4, 12.2±1.4 pps at 10 % MVC and 17.9±3.9, 16.5±1.7, 17.1±1.1 pps at 20% MCV contraction respectively. At 10% MVC the average firing presented statistical significant difference when comparing values at 90° and 110° as well as between 110° and 130°. At 20% MVC only average firing values between 110° and 130° were statistically different.

CONCLUSIONS: As expected from the muscle length/tension curve changing the ankle angle the MVC changes too. The largest value was at the neutral angle (110°). Lower or wider angles determined a reduction in the mechanical output. It can be hypothesized that at neutral angle the TA deploys the largest number of active cross-bridges and hence more efficient MU. At this angle the firing rate is the lowest, both at 10 and 20% MVC. This suggests that the CNS reaches the same relative effort (always stronger in absolute terms) with a lower neural drive towards the motoneuronal pool. On the basis of our results, obtained by means of a non invasive method, we can eventually summarize that muscle length influences the MU muscle fibres mechanical efficiency and this event is in turn reflected in reduction of MU FR.

O10.3 Decomposition of surface EMG Signals from Activities of Daily Living

Joshua C Kline, Bhawna Shiwani, Serge Roy, John Chiodini, Gianluca De Luca
Delsys, Inc and Altec, Inc

BACKGROUND AND AIM: Over the past 5 decades various attempts have been made to decompose the electromyographic (EMG) signal into constituent motor unit action potentials (MUAPs) to investigate the control of human movement. Our group has been working to advance technology to automatically measure the action potentials of individual motor units directly and noninvasively from the surface EMG signal. While systems currently used in the field have proven to be successful in providing measures of neural control during isometric or constrained cyclic contractions, there remains an unmet need for technology that is capable of measuring the motor unit contributions to activities of daily living, therapeutic exercises, or sports training.

Methods: we are advancing our decomposition algorithms to overcome three primary challenges of extracting motor unit data from sEMG signals recorded during dynamic movement: 1) tracking non-stationary changes in motor unit action potential shapes that occur with position and length changes of the muscle fibers, 2) improving the temporal resolution of firing rate measurements across dynamically varying activities, and 3) localizing firing detections amongst complex superpositions typically encountered in normal human movement. We tested these algorithms on n=6 control subjects (3 M, 3 F, age 22-68 yo) using sEMG signals recorded from dEMG sensors (Delsys Inc, Natick, MA) placed over the extensor digitorum, flexor digitorum profundus, biceps brachii and pronator teres muscles. Subjects participated in a variety of functional activities of daily living that involved coordinated use of the fingers, hand and forearm during tasks of object placement, eating and drinking. The accuracy of the detected action potentials and firings times was validated using the previously-published decompose-synthesize-decompose-compare method for all muscles, contractions and motor units.

Results: Across all subjects tested, the algorithms were able to identify a broad range of motor units (range: 5-24 per contraction), above the 90% accuracy benchmark. In all four muscles, motor unit firing behavior maintained an inverse hierarchical relationship between motor unit size and firing rate that varied in magnitude depending on the degree of synergistic involvement of each muscle in the specific movement. These results indicate that our sensors and algorithms provide a viable tool for assessing motor unit control mechanisms governing the contributions of different muscles to activities of daily living.

Conclusions: Importantly, this work marks a first step towards delineating the neural contributions to motor tasks associated with activities of daily living. Access to motor unit-based outcome measures provides new applications to modify exercise, guide training modalities and tailor rehabilitation protocols based on empirical measures of neuromuscular control.

O10.4 Estimation of the neural drive during vibration exercise by high-density surface-electromyography decomposition

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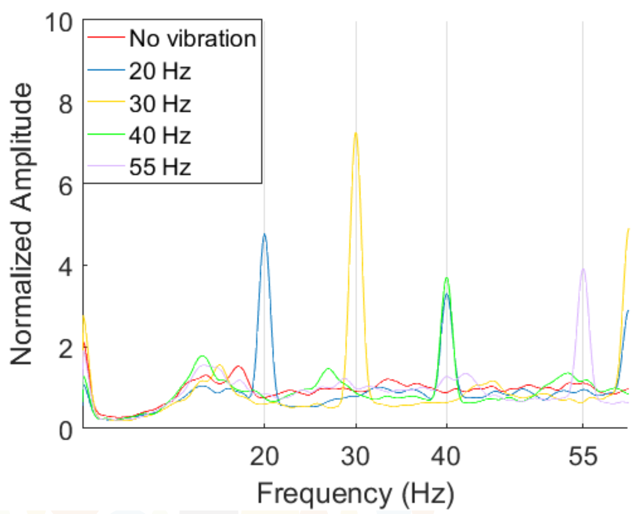
[1]Eindhoven University of Technology, [2]Università degli Studi di Brescia, Brescia, Italy, [3]Imperial college London

BACKGROUND AND AIM: Vibration Exercise (VE) has been suggested to increase motor unit (MU) synchronization, as evidenced by spectral peaks observed in the surface electromyography (sEMG). This effect has been partially ascribed to a specific reflex mechanism named tonic vibration reflex (TVR). However, other studies interpreted those spectral peaks as motion artifacts (MA). This study aimed at investigating the nature of those spectral peaks by decomposing the sEMG signal into individual MU action potential (MUAP) trains. To this end, low-intensity isometric contractions were executed with and without vibration, and high-density sEMG measurements performed during each contraction task.

Methods: Five healthy subjects volunteered in this study. They sat on a fitness bench with the back straight and elbow at 90 degrees. A force-modulated VE system generated an involuntary sinusoidal oscillating force applying to the dominant arm of the subjects. The subjects performed 30-s isometric contractions with different (randomized) vibration amplitudes and frequencies. The baseline force was set at 30% of the maximum voluntary contraction (MVC), measured by a load-cell embedded in the VE system, the vibration amplitude at 0 (no vibration), 12.5%, 25%, and 50% of the baseline force, and the frequency at 20, 30, 40, and 55 Hz. During each task, the sEMG was measured on the biceps by two 8×8 Ag/AgCl electrode grids (4-mm diameter, 8-mm inter-electrode distance) aligned with the muscle fibres. The ground was placed on the clavicle using an Ag/AlCl electrode with 1-cm diameter. The detected EMG signal was recorded by a 136-channel Refa amplifier sampling at 2048 Hz. For each sEMG data-set, MUAP pulse trains were extracted by a convolutive blind source separation technique. The power spectral density (PSD) of each MUAP train was estimated using Welch's method and then combined. A synchronization index (SCi) was calculated at the vibration frequency by normalizing the power around the vibration frequency (± 2Hz) with respect to the total power in the frequency band from 15 to 300 Hz. The difference in SCi between each vibration trial and control condition was assessed by Wilcoxon signed rank test.

Results: Clear MU synchronization was observed during VE (Fig. 1) and the SCis were significantly higher with respect to no vibration. In addition, an increase (not significant) in SCi was observed with increasing vibration amplitudes.

Discussion AND CONCLUSIONS: The SCi increase during VE indicates vibration-induced MU synchronization, confirming the spectral peaks at the vibration frequency to be mainly due to the reflex loop rather than MA.



O10.5 Sex-related differences in motor unit behaviour at 20, 40, 60, 80 and 100 percent of maximal isometric voluntary contraction.

J Greig Inglis, Justin Parro, David Gabriel
Brock University

BACKGROUND AND AIM: Christie and Kamen (2010) reported a "tendency" for males to have greater motor unit discharge rates (MUDR) than females, during maximal voluntary contractions (MVC). The current research therefore investigated MUDRs across force levels to identify potential sex differences.

METHODS: Forty-eight (F24; M24) college students performed isometric dorsiflexion contractions. Day 1 included anthropometric measurements and task familiarization. Day 2 included trials performed at 20, 40, 60, 80, and 100% MVC. The submaximal trial order was balanced by sex with MVC's performed pre and post. Contractions were 8-sec with 3-min rest. The force (JR3 Inc., Woodland, CA) was presented on an oscilloscope (Hitachi, VC-6525, Woodbury, NY) for feedback with target error bars (± 2.5%). Tibialis anterior electromyography (EMG) was recorded with an intramuscular quadrifilar electrode (Viasys Healthcare UK; Surrey, England) inserted below the electrically-identified motor point. Myoelectric activity was amplified (Grass P511; Astro-Med Inc., West Warwick, RI) and band-pass filtered (1-10 kHz). Force and EMG were sampled at 25.6 kHz (DASYTEC National Instruments, Amherst, NH). Motor unit action potentials were identified using EMGlab (www.emglab.net) and subsequently analyzed in Matlab (The Mathworks Inc.; Natick, MA). Data analysis was confined to the most stable portion (2-sec window, ± 2.5%) of the contraction.

RESULTS: As expected, a progressive increase in MUDR (pps) from 20% to 100% MVC was present in females (17.31±3.22 to 26.11±4.84, respectively) and males (15.36 ± 3.00 to 27.68 ± 4.47, respectively). However, at each submaximal force level females had a greater MUDR (Δ= 1.24 pps, 6.25%) and incidence of doublets (Δ= 49.03 discharges, 50.00%) compared to males (P's<0.01). Females had a greater coefficient of variation in MUDRs across all force levels compared to men (P<0.01). Sex differences could also be observed during the rate of force development (RFD); females had a lower RFD across all contractions and a greater incidence of doublets submaximally (P<0.01). Time to peak RFD was also generally longer for females (Δ= 24.64 ms, 10.50%).

CONCLUSIONS: Sex differences in MUDR may be related to elasticity of the muscle-tendon unit, as females would benefit from higher discharge rates and an increased incidence of doublets (Costa et al., 2012). Muscle pennation angle in females may have also been less optimal at the test position, compared to males (Manal et al., 2006). As contraction intensities increase so does pennation angle, which may explain why sex differences in MUDR variability decreased and MUDR differences disappeared at MVC.

O10.6 Relationship between motor unit coherence and nonlinear surface EMG features during isometric contraction

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University College Dublin

BACKGROUND AND AIM: The synchronous discharge of motor units, particularly in the beta-band (15-30 Hz) frequency range, has been linked to oscillatory cortical and sub-cortical processes. A reduction in corticomuscular coherence and in synchronization between pairs of motor unit (MU) has been shown with increasing force [1,2]. The beta-band coherence among populations of MUs in the first dorsal interosseous (FDI) was estimated to assess whether a systematic change occurred with changing muscle force. Nonlinear measures of signal complexity were also used to examine whether a corresponding change occurred in the structure of the surface EMG signal that would indicate altered MU synchrony [3,4]. Recurrence quantification analyses and sample entropy have been previously applied to surface EMG signals to capture changes in the underlying MU synchrony, however the exact relationship between MU coherence and these nonlinear measures is not fully established.

METHODS: Beta-band MU coherence was investigated in the FDI (N=10) during index finger abduction. Subjects increased force from 20% to 30% MVC, or decreased it from 30% to 20% MVC. Coherence in beta band was also investigated during separate contractions at 10, 20, 30 and 40% MVC. Discriminable MUs were extracted from the surface EMG using decomposition algorithms (Delsys, Inc.). Recurrence plots were estimated from the time-delayed phase space reconstruction of the EMG signals, and recurrence rate (%REC) and determinism (%DET) were calculated, in addition to the EMG sample entropy (SampEn).

RESULTS: There was a significant change in coherence across the force levels ($p<.01$). Post-hoc tests confirmed that beta-band MU coherence was higher during contractions at 10%MVC compared to 20%, 30% and 40%MVC. A significant change in coherence across force levels was also observed in %REC, %DET and SampEn ($p<.01$ for all), with 10%MVC differing from other force levels. In trials with two force levels, there was a significant decrease in coherence as force increased, decreasing by 43±32% from 10% → 20%MVC and by 31±28% from 20%→30%MVC. Conversely, there was a significant increase in coherence as force decreased, increasing by 277±283% from 30%→20%MVC and by 180±140% from 20% → 30%MVC. The changes in the recurrence quantification variables and sample entropy were consistent with changes in MU coherence for the decreasing force trial.

CONCLUSIONS: In this study, beta-band intra-muscular coherence decreased at higher force levels. A simultaneous decrease in surface EMG %DET and %REC was observed, in addition to an increase in sample entropy, all of which are consistent with an increase in MU synchrony. Although the nonlinear measures closely followed the changes in MU coherence during decreasing force trials, they were less consistent during the increasing force trials. In these trials other factors may be influencing the ability of these measures to detect MU synchrony, including changes in muscle fiber conduction velocity and MU recruitment [5].

[1] Ushiyama et al. (2011). J Neurophysiol,106(3),1379-1388. [2] Kline & DeLuca (2016). J Neurophysiol,115(1),178-192. [3] Webber (1995), J Appl Physiol,78(3),814-822

ORAL PRESENTATIONS

Sunday, 1st July

Sunday July 1st

S6 SYMPOSIUM: EMG SIGNAL DECOMPOSITION: VALIDATION AND IMPACT IN OUR PHYSIOLOGICAL UNDERSTANDING OF NEURAL CONTROL OF MOVEMENT

S6.1 Identification of motor unit firings at different speeds of dynamic muscle contractions

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University of Maribor, Faculty of Electrical Engineering and Computer Science

BACKGROUND AND AIM: Identification of motor unit (MU) firings provides direct insight into neural codes that govern human movements. Until now, it has largely been limited to isometric muscle contractions. The latter have been frequently used as a benchmark of general MU behaviour, although the relation between the muscle excitations in dynamic and isometric contractions is largely unknown. New methodologies for MU identification in dynamic contractions are required but currently lacking.

Methods: We designed an algorithm that identifies MU firing patterns from dynamic high-density surface electromyograms (hdEMG). The method is based on nonstationary convolutive data model and uses Pulse-to-Noise Ratio (PNR) metric [1] to assess the sensitivity of each individual MU identification to MUAP changes in dynamic muscle contractions. We tested this methodology on signals from biceps brachii, measured by array of 13×5 electrodes (OT Bioelettronica, Italy, interelectrode distance of 8 mm). First, MU firings were identified during isokinetic 80 s long full elbow flexion in five young males. MUAPs were then assessed by spike triggered averaging of 36 consecutive 10 s long EMG epochs that overlapped for 6 seconds. MU spike trains were generated by the model proposed in [2]. 60 s long constant 10 %, 30 % and 50 % muscle excitations were simulated, resulting in 105, 155 and 178 active MUs, respectively. Different muscle contraction speeds were generated by simulating 2, 3, 6 and 12 full flexion-extension ramps in 60 s. Each generated MU spike was convolved with one of the 36 dynamic MUAP shapes, selected according to the simulated level of muscle shortening (Figure 1).

Results: On average, the method identified 14 ± 1, 13 ± 2 and 11 ± 1 MUs per 10, 30 and 50% muscle excitation, respectively. MUs were identified with average sensitivity > 98% and PNR > 28 dB. The number of identified MUs and their accuracy did not depend on the speed of muscle contraction (paired t test, $P > 0.05$).

Conclusions: The presented method demonstrated significant robustness to simulated speeds of muscle contraction and accurately identified relatively large number of MUs. Further tests on different muscles and larger set of simulated and experimental signals are required. However, the results on full flexion-extension of biceps brachii muscle are encouraging, especially as the geometrical changes due to dynamic contraction are relatively large in this muscle.

ACKNOWLEDGEMENT: This study was supported by the Slovenian Research Agency (project J2-7357 and Programme P2-0041).

[1] A. Holobar, M. Minetto and D. Farina, Accurate identification of motor unit discharge patterns from high-density surface EMG and validation with a novel signal-based performance metric, Journal of Neural Engineering, vol. 11, no. 1, p. 016008, 2014. [2] A.J. Fuglevand, D.A.Winter, A.E.Patla, Models of recruitment and rate coding organization in motor-unit pools, J. Neurophysiol. 70, pp. 2470-88,

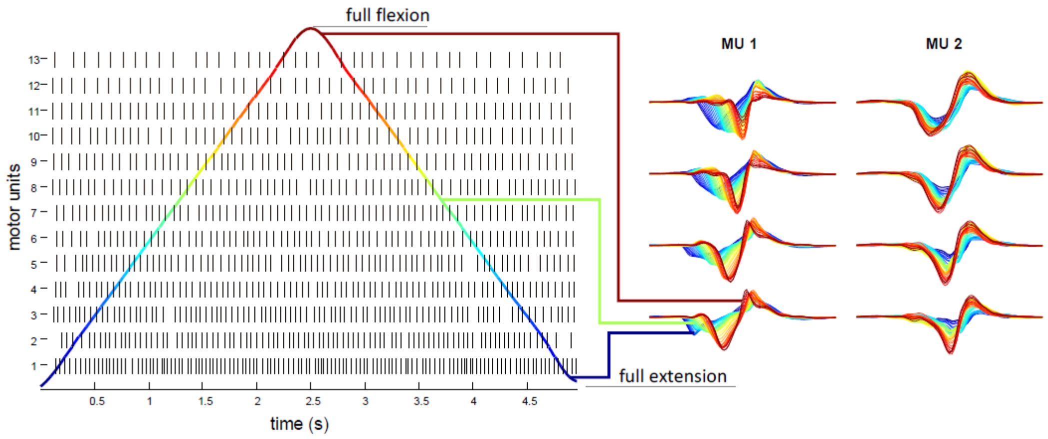

Figure 1: MU firing patterns identified from hdEMG in simulated dynamic contraction of biceps brachii with muscle excitation level set to 30 % (left). Each vertical bar denotes one MU firing. Coloured line depicts the level of simulated muscle shortening. For clarity reasons, only one out of 12 simulated muscle shortening ramps is depicted. When simulating hdEMG, we used experimentally determined MUAPs, estimated at 36 different levels of biceps brachii shortening (right). Different colours depict MUAP shapes at different levels of muscle shortening. For clarity reasons, MUAPs of only two MUs in only four hdEMG channels are depicted.

S6.2 Motor unit firing properties in the biceps brachii of hemiparetic stroke survivors studied using template-based recognition algorithms: contributions to muscle weakness

William Z Rymer
Shirley Ryan AbilityLab

Background and Aims We examined motor unit discharge in paretic muscles of hemispheric stroke survivors using surface EMG recordings collected over biceps brachii muscles. Motor units were recorded using a Delsys sensor array, and further identified using template-based algorithms developed by Deluca and colleagues (Nawab et; al., 2010).

Methods: In 11 hemispheric stroke survivors, we were able to record from more than 3000 motor units over a range of isometric muscle contractions of elbow muscles, primarily recording from biceps.

Results: Our primary focus was to determine whether the recruitment and firing rate properties of motor units recorded from impaired biceps brachii muscles were systematically different from analogous discharge properties in contralateral biceps muscles of hemispheric stroke survivors. Our findings were that there were systematic reductions in mean firing rate for the majority of subjects, accompanied by overt recruitment compression with rising force. While these changes were statistically significant the absolute magnitude of rate reductions was relatively modest. These data confirm the utility of template-based algorithms for motor unit data extraction from the surface electromyogram. We did not yet attempt two-source validation for these data (in which surface unit recognition was confirmed with appropriate intramuscular recordings). Nonetheless, interval histogram statistics suggested that overall error rates were relatively small since the number of unrealistically short intervals was less than 3% of total intervals recorded, and there were relatively few very long intervals, representing dropped spikes.

Conclusion: Take an overall, the changes in firing properties and in recruitment profiles for the biceps brachii units in paretic muscles were modest in scale and unlikely to have made major contributions to reduced voluntary force generation. We conclude that reduced descending commands were likely to be the primary cause of voluntary weakness, compounded by associated muscle fiber atrophy. Nawab SH, Chang SS and DeLuca CJ, 2010 High-yield decomposition of surface EMG signals Clin. Neurophysiol. 121 1602-15

S6.3 Associations between motor unit activity during steady isometric contractions with lower leg muscles and mobility in older adults and persons with multiple sclerosis

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University of Colorado

Background: Mobility limitations significantly impact the quality of life for both healthy older adults and persons with multiple sclerosis (MS). The declines in mobility involve significant adaptations within the nervous system, including the remodeling of motor unit populations.

Methods: Older adults (n = 20) and persons with MS (n = 23) participated in separate clinical trials to evaluate the capacity of neuromuscular electrical stimulation to improve mobility, which was assessed before, during, and after each intervention. In addition, participants performed steady submaximal contractions with the plantar flexor and dorsiflexor muscles during which EMG signals were recorded with high-density electrode grids (W-EMG, Bitron spa and LISiN-Politecnico di Torino, Turin, Italy).

Results: Our analytical approach comprised an evaluation of the associations between the mobility assessments and the motor unit discharge characteristics during the steady contractions in each cohort. The number of motor units included in the analysis for each muscle (tibialis anterior, medial gastrocnemius, and soleus) ranged from 422 to 1,634 for the two groups of subjects. Multiple-regression models were able to explain from 24% to 47% of the variance in the tests of walking endurance, maximal walking speed, and balance for each group of participants. The predictor variables differed for each group of participants but included mean interspike interval (ISI) for soleus, mean ISI for medial gastrocnemius, and the kurtosis of the ISI distribution for tibialis anterior. The other explanatory variables were MVC torque for the dorsiflexors, force steadiness for the plantar flexors, and the rating of perceived exertion--a measure of perceived fatigability--at the end of the test of walking endurance.

Conclusion: The capacity of motor unit discharge characteristics to partially explain the variance in performance on tests of mobility in older adults and persons with MS suggests that differences in the motor unit activity required to perform each steady contraction inform us about the extent of motor unit remodeling experienced by these individuals.

S6.4 Identifying the organization of synaptic input to motoneurons in humans

CJ Heckman
Northwestern University

Motoneurons are unique in being the only neurons in the CNS whose firing patterns can be easily recorded in human subjects. It has long been appreciated that the connection of motoneurons to their muscle fibers allows their action potentials to be amplified and recorded but only recently has it become possible to simultaneously record the firing pattern of many motoneurons via array electrodes placed on the skin. These population firing patterns contain detailed information about the synaptic organization of motor commands and we focus on identifying parameters in these firing patterns that are directly linked to specific features of this organization. The detailed firing patterns of populations of motoneurons are recorded using surface array electrode methods. The extensive data on processing of synaptic input by motoneurons obtained from animal preparations is used to facilitate the interpretation of these firing patterns. It is now well established that motor commands consist of three components, excitation, inhibition and neuromodulation; the importance of the third component had become increasing evident. Firing parameters linked to each of the three components will be presented, along with consideration of their limitations. Future work based by realistic computer simulations of motoneurons may allow quantitative reverse engineering of human motoneuron firing patterns to provide good estimates of the relative amplitudes and temporal patterns of all three components of motor commands.

S6.5 Motor Unit Population Analysis From High-Density EMG

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Classic methods for the identification of individual motor units are based on selective invasive EMG systems. While these approaches have provided us the means for identifying basic physiological principles underlying the neural control of muscle force, they have been limited by the very small proportion of concurrently sampled motor units. Because of this limit, neural mechanisms based on motor unit population coding, such as neural connectivity, have been difficult to decipher. Recent methods for motor unit analysis have overcome the sample limitation by the use of high-density electrode systems that comprise tens to hundreds of closely spaced surface or intramuscular electrodes. The large spatial sampling provided by these systems allows the identification of a substantial proportion of active motor units during natural tasks in a broad range of conditions. With these systems, established principles of motor unit behavior have been revisited using a population analysis. For example, the functional meaning of motor unit synchronization has been explained by identifying the common synaptic input received by motor neuron pools and by extending the concept of intramuscular coherence to a motor unit population level. The current high-density EMG approaches for motor unit identification have been validated in a variety of conditions, such as ballistic contractions, and in several pathological cases, such as tremor. Their broad applicability provides new perspectives in the study of the neural determinants of movement and their adaptations with fatigue, training, and pathology.

O11 REFLEXES & NEURAL PATHWAYS II

O11.1 Wrist stretch reflex responses are modulated by expectancy

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TU Delft

Background and Aim: Behavioural studies have demonstrated that cognitive processing such as expectancy have an effect on the preparation of voluntary movements. Typical experiments involve motor preparation paradigms in which reaction times (RTs) decrease where expectancy is induced within a variable fore-period (time between a cue and a movement response signal, RS). Excitability of the corticospinal (CS) pathways increases with expectancy to initiate movement [1]. However, the contribution of spinal and cortical neural processing to the increased excitability is still unknown. Here, we measured stretch reflexes at various levels of expectancy in order to investigate the spinal contributions that allow the Central Nervous System to proactively respond to uncertain visual stimuli.

Methods: Sixteen healthy volunteers (25±1.8 years) participated in the experiment, which involved a motor preparation paradigm with a variable-delay simple-reaction task. Expectancy of the RS, that cued the prepared voluntary movement, was induced at four possible time-locations within a single trial (Fig.1). All four time-locations had an equal probability of showing the RS. This variation increased by a predetermined conditional probability, i.e. whenever the RS did not occur at a time-location, the likelihood for the event occurring at the remaining time-locations increased. CS excitability was assessed by the measurement of stretch reflex responses (SRs) in the EMG of the flexor carpi radialis. In some trials, a transient position perturbation was given using a wrist manipulator to apply muscle stretch AT or BETWEEN the expected RS.

Results: RTs linearly decreased according to the RS probability, which is in accordance with previous literature. Surprisingly, the short latency response varied, regardless the muscle activation, showing both depression and excitation with different probabilities of the expected RS. In contrast, the long latency response showed an abrupt excitation increment in the last expected RS, i.e. at the highest probability.

Conclusion: Both SRs were modulated by expectancy but showed different behavior. These findings suggest distinct mechanisms that modulate excitability in spinal and CS pathways. The measurement of stretch reflex responses allows to explore not only changes in CS pathways but the possible neural mechanisms that contribute to the control of limb stability. During the preparation of fast responses, expectancy of visual stimuli enhances perceptual mechanisms that modulate voluntary and involuntary -reflexive- motor behavior.

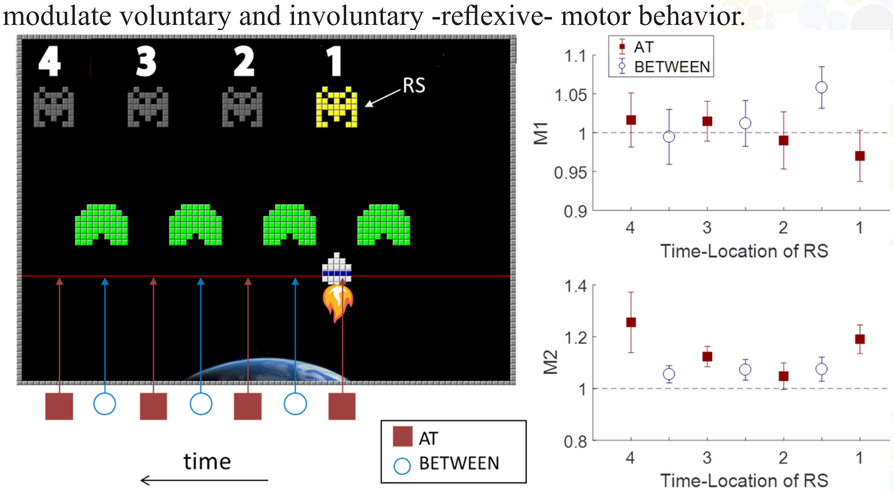

Fig. 1: The task resembled a game. During a single trial, the rocket moved from right to left automatically at constant speed. The appearance of an alien was considered the RS. In 60% of the trials, a single RS was shown at one of the possible time-locations, participants responded by moving the rocket upwards by flexing the wrist. In remaining 40% of the trials, a position perturbation was applied AT or BETWEEN an expected RS.

O11.2 Cold-water immersion of a single limb reduces inhibition and enhances facilitation in the motor cortex of the opposite limb

Justin Kavanagh, Eden Delahunty, Daniel Mckeown, Jacob Thorstensen
Griffith University

BACKGROUND AND AIM: Performing brief strong contractions with a single limb is often accompanied by unintended muscle activity in the contralateral homologous muscle. At the spinal level, reflex activity appear largely unaffected in the contralateral resting muscle. However at the cortical level, TMS-induced motor evoked potentials are increased in the contralateral resting limb when maximal effort contractions are performed. Although a body of evidence indicates that crossed-effects are elicited via strong voluntary contractions, it is unknown if altering sensory input of one limb is capable of changing motor activity on the opposite side of the body.

Methods: The current study examined if immersing a single upper limb in very cold water (4 degrees Celsius) affected inhibitory and facilitatory motor cortex circuits in the opposite non-immersed limb. Eight healthy subjects (22.1 ± 2.7 yr) participated in the experiment and standard paired-pulse TMS protocols were used to assess motor cortex circuitry associated with the non-immersed limb. Resting motor threshold, short interval intracortical inhibition (SICI), long interval intracortical inhibition (LICI), and intracortical facilitation (ICF) were assessed for the extensor carpi radialis brevis muscle in the non-immersed limb.

Results: Visual analogue scales confirmed that each subject experienced significant changes in pain and temperature due to cold water immersion of a single limb. Resting motor threshold did not differ between control and water immersion conditions. Although no changes were detected for LICI, SICI was significantly reduced in the opposite limb during the immersion condition compared to the control condition ($p = 0.035$). This reduced inhibition in motor cortical circuits corresponded to increased ICF during the immersion condition compared to the control condition ($p = 0.013$).

Conclusions: The presence of a localised painful stimulus on one side of the body affected cortical circuits responsible for activating muscles on the opposite side of the body. This suggests that functional relationships exists between sensory areas of one hemisphere and motor areas of the opposite hemisphere.

O11.3 The Interference of Tonic Frontalis Muscle Activity On The EEG Signal

Gizem Yilmaz, Abdullah Salih Budan, Kemal S. Türker
Koc University

BACKGROUND AND AIM: Electrodes for recording electroencephalogram (EEG) are placed on or around cranial muscles; hence their electrical activity may contaminate the EEG signal even at rest conditions. Previous studies reported electromyographic (EMG) interference from temporalis, frontalis, ocular and neck muscles. When contracted voluntarily the EMG activity of frontalis was found to contaminate the EEG. However, for our knowledge, no studies have evaluated the interference of frontalis muscle activity on EEG electrodes, particularly at the frontal sites, at rest conditions. Therefore, our aim in this study was two folds: 1) to investigate the tonic single motor unit (SMU) activity at rest, 2) to evaluate the myogenic interference from frontalis SMUs onto EEG signal. Therefore, we hypothesized that the tonic activity of frontalis would contaminate the EEG signal.

Methods: In 7 healthy adults EEG activity from 32 scalp locations and single motor unit (SMU) activity of frontalis muscle (right and lefts sides) were recorded in eyes open, sitting, relaxed experimental conditions. The EEG signal was spike triggered averaged (STA) using the action potentials of SMUs as triggers to evaluate their re?ections at various EEG recording sites.

Results: In 5 of 7 subjects, we detected tonic motor unit activity in left and/or right sides of frontalis. The total of 33 SMUs were extracted (16 from right, 17 from left side). We continued further analysis with these SMUs. Resting frontalis SMU activity generated prominent interference potentials with different amplitudes on EEG electrodes in the proximity of the recorded SMU, particularly Fp1, F3, F7 for left SMU and Fp2, F4, F8 for right SMU. Figure 1 illustrates an SMU-interference on Fp1, F7 and F3 electrodes from a left-side SMU. Eleven of 16 left side SMUs generated prominent interference potentials on Fp1, 9 of 16 on F3 and 5 of 16 on F7 electrode. Similarly, 7 of 17 right side SMUs generated prominent interference potentials on Fp2, 3 SMUs on F4 and 6 SMUs on F8 electrode. Interference was not notable at the scalp sites that are relatively far from the recorded SMU.

Conclusions: Our preliminary findings indicates the need for careful evaluation of EEG-recording since the muscle activity may contaminate the signal even at rest conditions where no voluntary muscle activation is expected. Frontalis muscle has not been known with tonic activity before, however, its tonic activity may contaminate the frontal-temporal EEG locations even though the electrodes are not covering the whole muscle. Considering other facial and neck muscles and the great number of SMUs they exhibit, we suggest a careful re-evaluation of EEG signal properties due to its susceptibility to muscle activity artifacts even under the rest conditions.

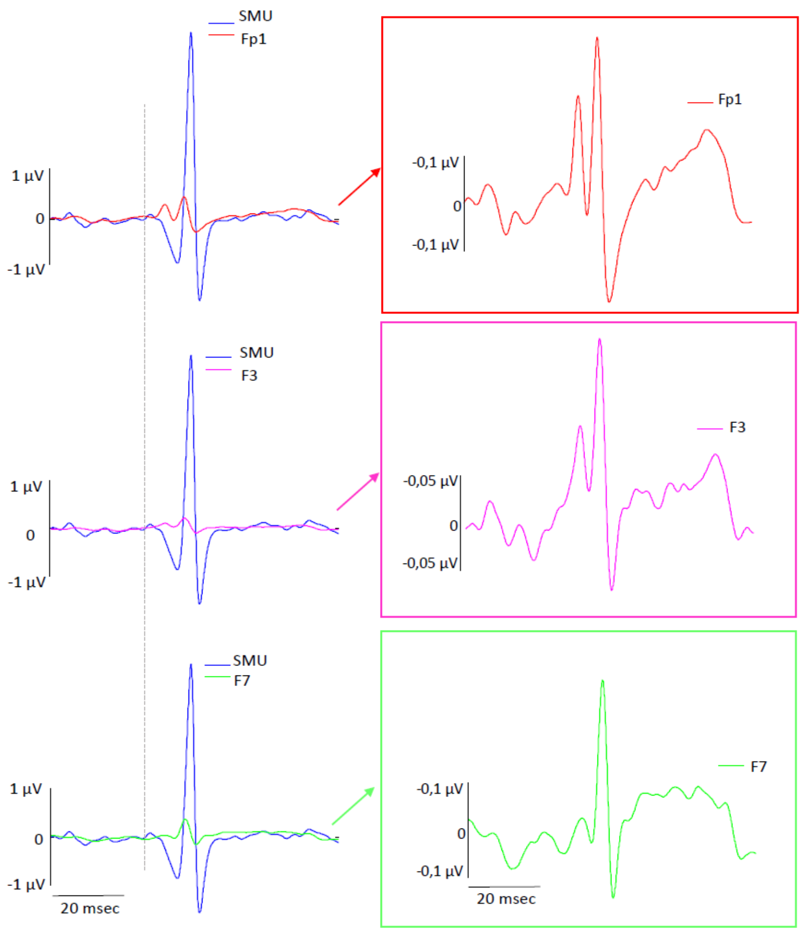

Figure1: Frontalis SMU-interference potentials from Fp1(top), F3 (middle) and F7 (bottom). Left column shows SMU shape and interference potentials overlapped, righ column zooms into interference potential shapes. The SMU number used in averaging was 2200 spikes.

O11.4 Effect of aerobic exercise on electroencephalogram parameters and cognitive functions in patients with mild cognitive impairment

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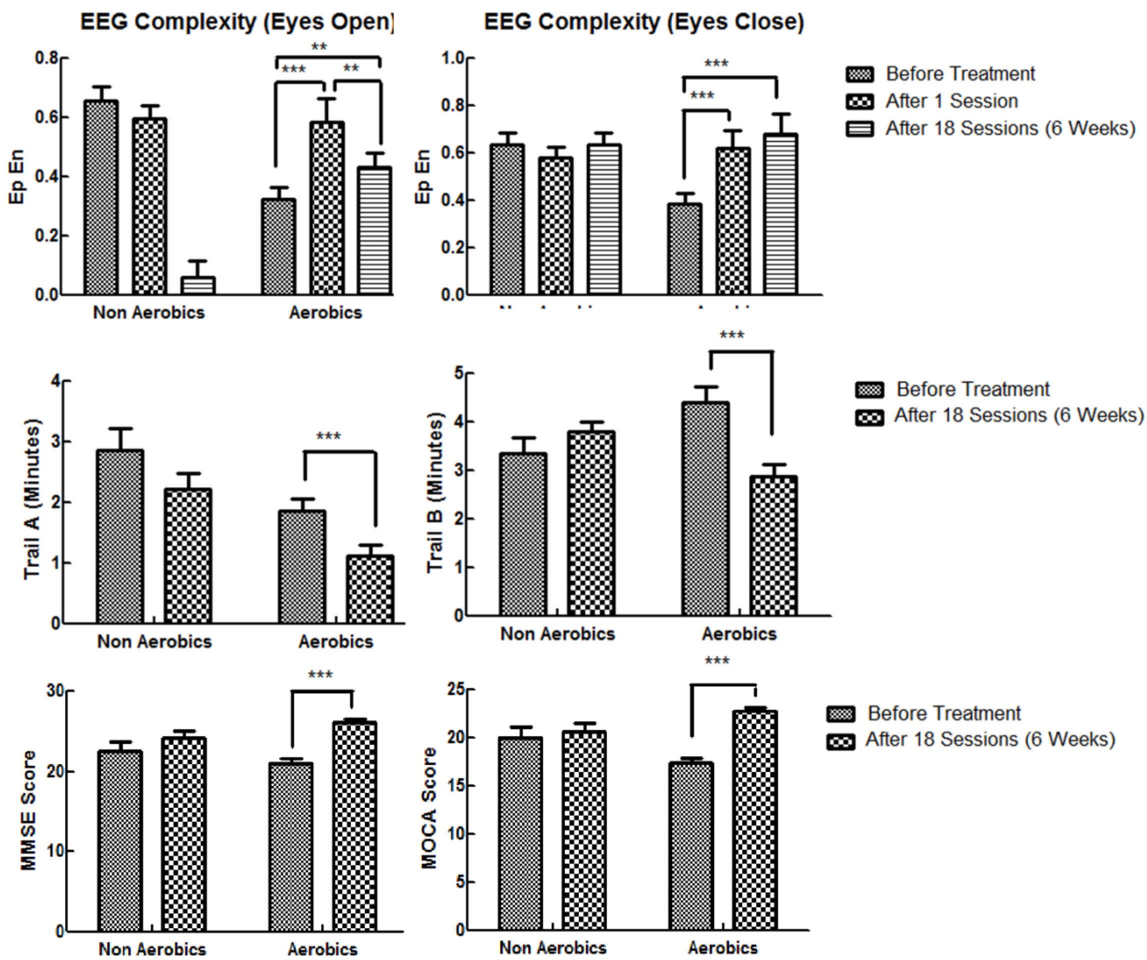
BACKGROUND AND AIM: Mild Cognitive Impairment (MCI) is becoming a serious problem for developing countries with growing age of the population. There is no specific curative treatment for these patients. The objective of this study was to determine the short and long-term effects of aerobic exercise on electroencephalogram parameters and cognition of MCI patients.

Methods: A randomized control trial was conducted at Railway General Hospital Rawalpindi, Pakistan. A total of 41 MCI patients were selected and randomly divided into aerobic exercise treated group (n=21) and No exercise group (n=20). Acute effect of exercise was measured after one session of exercise and long-term effects were measured after 18 sessions (6 weeks) intervention. Outcomes measured were slowness and complexity of EEG, mini-mental standardized examination (MMSE), Montreal cognitive assessment (MoCA), trail making test A and B before and after treatment.

Results: One session of aerobic exercise showed significant improvement in the cognition of the aerobic treated group as compared to the No exercise group. After 18 sessions (6 weeks) of treatment of aerobic exercise, there was a significant difference in slowness and complexity of EEG, also in MMSE, MoCA, trail making test A and B.

Conclusions: Aerobic exercise showed both acute and chronic cognitive improvement in patients with mild cognitive impairment and can be used to improve cognitive function.


EEG Complexity (Eyes Open)
EEG Complexity (Eyes Close)
Ep En
Non Aerobics
Aerobics
Before Treatment
After 1 Session
After 18 Sessions (6 Weeks)
Trail A (Minutes)
Trail B (Minutes)
Before Treatment
After 18 Sessions (6 Weeks)
MMSE Score
MOCA Score
Before Treatment
After 18 Sessions (6 Weeks)

O11.5 A single session using a novel music-motor therapy app increases corticomotor excitability in healthy young adults

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BACKGROUND AND AIM: Music-motor therapy involves the therapeutic application of music and has shown to effectively enhance movement in individuals with neurological injury and disorders, including stroke and Parkinson's Disease. Music-motor therapy protocols use rhythmic cues and exploits the extensive auditory-motor connections in the human cortex to facilitate movement. However, the specific underlying mechanisms of music-motor therapies and how they affect corticomotor excitability are currently not well-understood. We developed a novel mobile software application, called GotRhythm, which incorporates wireless sensors and real-time biofeedback to deliver a music-motor therapy to clinical populations. GotRhythm training involves repetitive movement to music, in time to a specified beat. We measured the effect of GotRhythm on motor learning and corticomotor excitability, using Transcranial Magnetic Stimulation (TMS), in healthy adult participants.

Methods: Adult participants (n=20, 7 males) completed the current study, undergoing 30mins of GotRhythm training, a control motor task (a standard control thumb abduction task previously shown to induce robust motor learning and increase corticomotor excitability) or a rest control (in separate experimental conditions). Two apps (GotRhythm and motor control) collected rhythmic accuracy data and thumb acceleration data during training sessions to measure motor learning. Corticomotor excitability was assessed using single- and paired-pulse TMS of the left primary motor cortex to assess changes in motor-evoked potentials (MEPs) recorded from a hand muscle that is engaged during training.

Results AND CONCLUSIONS: Results indicate a single session of GotRhythm significantly increased corticomotor excitability, after 30mins of training ($p<.05$). No evidence of motor learning (increase in accuracy) was found following GotRhythm training. We conclude that GotRhythm is effective in increasing corticomotor excitability and may provide a useful tool for inducing neuroplasticity in clinical populations such as stroke patients.

O11.6 Reliability of corticomotor excitability analyses using transcranial magnetic stimulation on two lower extremity muscles

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Neuromuscular control of lower extremity (LE) movements during landing is an area of research focus on knee injury prevention and rehabilitation. However studies thus far, have only used electromyography (EMG) and kinematics to determine motor control processes underlying different landing strategies. Given that the commands for movement originate from the motor cortex, revealing motor cortical function that may underlie LE movement could assist in determining optimal intervention. Transcranial magnetic stimulation (TMS) is an ideal instrument for the assessment of corticomotor excitability (CE) and has been used extensively in upper limb studies to determine brain-behavior relationships. For LE weight-bearing movement strategies, it is important to accurately measure the CE of the gluteus maximus (GM) and vastus lateralis (VL). Given large variability of the LE TMS measures that exists due to small representation in primary motor cortex (M1) and large threshold, we sought to determine the most reliable method for testing CE of LE muscles. The aim of the study was to compare the reliability of two different methods of analysis for the stimulus-response CE curves of VL and GM.

Methods: Ten healthy subjects (27.2± 4.8 years old, 68.4 ± 15.0 kg) were recruited. Two TMS tests were conducted within 3 days and the subjects were asked to keep their daily routines as consistent as possible for the testing days. TMS data was acquired using a single-pulse TMS with a double-cone coil, and the motor-evoked potentials (MEPs) were obtained from the GM and VL representation of M1. Hotspot and active motor threshold (AMT) for each muscle were determined during 20% maximal voluntary isometric contraction (MVIC). The following stimulus-response procedures to determine the input-output curves (IOC) for each muscle were: 1) over the hot spot, 11 stimulation intensities ranging from 100% to 200% AMT with 10% increments were delivered; 2) ten pulses were applied for each intensity; 3) the average peak-to-peak amplitude of the 10 MEPs were then normalized to the EMG signal obtained with 20% MVIC of each muscle. The IOC data were analyzed using two analysis methods: 1) a sigmoid curve fitting with the MEP average from each stimulation intensity, 2) a linear best-fit line for MEP averages obtained from stimulation intensities between 100% AMT to maximal MEP. Random-effect intra-class correlation (ICC) coefficients were calculated to evaluate between day test-retest reliability of the 1) maximal slope of the sigmoid curve and 2) the slope of the linear best-fit line.

Results: The ICC of the maximal slope for the sigmoid method was 0.47 for GM and 0.83 for VL; the ICC of the slope for the linear best-fit line was 0.78 for GM and 0.96 for VL.
Conclusions: The linear method for CE of VL and GM was more reliable than the sigmoid method. Therefore, the linear method should be used in future studies determining the role of CE in the motor control of LE movement during landing.

Table 1. The ICCs and 95% CIs of the two methods of each muscle

	ICC	95% CI(Lower)	95% CI (Upper)
GM sigmoid method	0.47	-1.57	0.87
GM linear method	0.78	0.18	0.95
VL sigmoid method	0.83	0.31	0.96
VL linear method	0.96	0.83	0.99

S7 SYMPOSIUM: ULTRASOUND ELASTOGRAPHY – WHAT ARE WE MEASURING IN MUSCLE?

S7.1 Temperature Decouples the Effects of Stiffness and Tension on Ultrasound Shear Wave Velocity

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BACKGROUND AND AIMS: Shear wave elastography offers a simple way to measure the material properties of biological tissues. It has great potential to detect muscle abnormalities, but the link between muscle properties and elastography is uncertain. Ultrasound shear wave velocity (SWV) is related to the shear modulus. In some simple materials, such as homogeneous isotropic materials, the shear modulus is related to Young's modulus. However, muscle is more complex. Tension in a muscle is likely to contribute to the shear modulus. A further complication is the stiffness and force of a muscle co-vary with activation because they both are a function of the number of attached crossbridges. It remains uncertain if SWV provides a measure of force and or stiffness. Our previous work shows whole muscle force and stiffness, along with the geometry of muscle and tendon, can be used to estimate specific tension and the specific stiffness of muscle tissue. We measure short range stiffness (SRS) by short quick stretches, since the traditional methods used to measure Young's modulus cannot be used on active muscle. Therefore, SRS is analogous to Young's modulus, but measured at higher frequencies. We are able to compare SWV to tension and SRS in the same section of an active and passive muscle. Our long term goal is to compare SWV to specific force and SRS in a variety of different muscle architectures. We begin with cat soleus and test the hypothesis that SWV is a function of force and is independent of SRS.

Methods: We took advantage of temperature to alter muscle SRS while holding force constant. We investigated the cat soleus muscle (n=4) while measuring muscle stiffness, force, and SWV. All measures were made during maximum activation while varying muscle temperature between 26° and 38°. The temperature of the muscle was regulated by controlling the saline bath in which the cat hind limb was submerged. Nearly constant force levels were achieved by supramaximal activation via sciatic nerve stimulation at optimum muscle-tendon unit length.

Results At maximal activation at 38oC, we measured a mean tension of 230.6±4.7 kPa, a SRS of 6.5±0.3 MPa, and SWV of 15.9±1.7 m/s. A model for homogeneous isotropic materials predicts Young's modulus of 758 kPa for 15.9 m/s. This is off by an order of magnitude and clearly not an acceptable model for muscle. We found that a temperature-dependent change in SRS caused a change of SWV, even at nearly constant isometric force. SRS estimates of Young's modulus decreased from 4.0 ± 0.3 MPa to 3.3 ± 0.3 MPa (18%, $p<.001$) as temperature was increased from 26°C to 38°C. Shear modulus estimated from SWV decreased from 0.32 ± 0.06 to 0.28 ± 0.06 MPa (12%, $p<.001$) for these same conditions. There was no significant change in muscle force with temperature (0.35% change, $p=.184$).

Conclusions SWV is influenced by SRS so we reject our hypothesis that it is solely a function of tension. However, we cannot discount SWV is also a function of tension.

S7.2 Shear Wave Velocity Varies in Human Muscles with Different Architectures Even When Activated to the Same Percent of Maximal Force

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BACKGROUND AND AIM: With the increasing use of shear wave (SW) ultrasound elastography for quantifying mechanical properties of muscle and its potential use in the clinical setting, it is important to understand the effect of different muscle properties on this technique. Although there is evidence that SW velocity varies at different muscle lengths and activation, it remains unknown whether SWs propagate similarly across different muscles and if not, what causes the difference. Shear wave ultrasound elastography allows estimation of tissue stiffness by measuring the velocity of SWs propagating through tissue. SWs propagate slower in the transverse plane (across fascicles) compared to the longitudinal plane (along fascicles); thus, the anisotropic nature of muscle affects the measurement of SW velocity. Architectural differences across muscles (e.g. pennation angle, fascicle length, number of aponeuroses) may have similar effects on stiffness estimates, even when the transducer is oriented parallel to the main axis of a muscle. For example, differences in pennation angle will result in a different relative angle between the main fiber axis and the direction of propagation of the SW. As anisotropic properties vary with contraction, the relationship between SW velocity and fiber tension may change when the SW does not travel parallel to the main fiber axis. It is unknown whether using SW elastography to compare stiffness across muscles of different architecture may result in inaccurate assessment. Thus, we tested the hypothesis that SW velocity does not change across muscles with different architecture at the same activation level.

Methods: We investigated three muscles in the human upper and lower extremities: biceps brachii, medial gastrocnemius, and tibialis anterior. Electromyography signals (EMGs) were used as a proxy for force of the targeted muscle. Each subject performed isometric contractions at different activations (0 to 50% of maximum voluntary contraction in 5% increments) while SW propagation velocity, EMGs, joint torque and force, were collected. The ultrasound transducer was aligned parallel to the aponeurosis and the fascicle plane. We obtained architectural parameters (fascicle length and pennation angle) from B-mode ultrasound images.

Results: ANOVA on an initial sample ($n=3$) showed that SW velocity across the three muscles did not differ in passive conditions ($F=2.47$; $p=.086$). However, under activation, the relationship between SW velocity and activation level was substantially different ($F=22.38$; $p<.001$).

Conclusions: Given the architectural differences between these muscles, these data provide a preliminary indication that muscle architecture may influence how SWs propagate in muscle. If so, comparison across muscles would be difficult, even when controlling activation level. Further investigation is needed to quantify the extent of changes in the elastogram and how these changes relate to specific muscle architectural features.

S7.3 Physiologic and Technical Considerations for Implementing Shear Wave Elastography in Musculoskeletal Applications

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BACKGROUND AND AIM: Shear wave ultrasound elastography (SWE) has emerged as a valuable tool in musculoskeletal imaging - enabling the quantification of tissue material properties in near real-time. The many benefits of ultrasound - non-invasive, accessible, affordable, and rapid results - underscore the danger of applying a technology such as SWE without a foundational understanding of the physics involved. A number of studies have outlined SWE technique in musculoskeletal applications, including the importance of transducer orientation relative to muscle architecture, and minimizing transducer pressure and motion. Urban et al. also note the necessity of clear terminology regarding tissue material properties, as well as the importance of publishing results of shear wave speed, in contrast to the variety of other reported values often found. As scientists and clinicians continue to explore the many applications of SWE, we present our recent studies identifying additional physiologic and technical considerations for implementing SWE. Our first study examined the relationship between exercise training and skeletal muscle shear wave speed; our second study evaluated the limitations in distinguishing small targets, such as tendon, nerve, or small muscles.

Methods: Training - 36 healthy subjects (9 untrained, 27 exercise-trained) participated. We collected SWE images of the biceps femoris long head and semitendinosus at 3 knee angles. We acquired all images using the SL10-2 transducer on the Supersonic Aixplorer scanner in SWE mode. We used a full-factorial repeated measures ANOVA to evaluate effects of sex, training status, muscle, and knee angle on shear wave speed. Small targets - We obtained measurements of a CIRS 049A elasticity QA phantom using a Supersonic Aixplorer scanner with SL10-2 and SL15-4 transducers, and a GE Logiq E9 XDclear 2.0 scanner with the 9L-D transducer. We scanned 10.4, 6.5 and 4.1mm-diameter cylinders with reference nominal Young's moduli of 45 and 8kPa at 3cm depth in a 25kPa uniform background.

Results: Training - We found a significant interaction for exercise training and knee angle, with shear wave speed at 30º knee flexion significantly higher for exercise-trained compared to untrained ($p<.0001$). There was also a significant interaction for knee angle and muscle ($p=.0255$). Small targets - Differences in shear wave speed between transducers for any given target ranged from 2.1%-16.9%. Measured speeds for small targets were closer to the background material's reference shear wave speed for all transducers. SL15-4 transverse measurements were the closest to reference values for all targets.

Conclusions: In addition to already established practices accounting for muscle activation and orientation, minimizing transducer pressure and motion, and ensuring accurate terminology and data reporting practices, we encourage investigators and clinicians to consider subject activity level, and to exercise caution when evaluating small targets.

S7.4 Shear-wave elastography in various muscles and conditions in humans

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We have been exploring the assessment of mechanical properties and activity of human muscles by utilizing their small mechanical oscillations, including mechanomyography, for over 20 years. It was about 8 years ago when we were excited at the first observation of apparently reasonable responses in the measurement of ultrasound shear-wave elastography on human muscles (Shinohara et al., Muscle & Nerve, 2010). Since then, as one of the first research groups who were fascinated by the potential applicability of the technology to human muscles, we have been involved in addressing several essential issues that may influence the utility of shear-wave elastography in human muscles. Validity of the most popular ultrasound shear-wave system (Aixplorer, Supersonic Imagine, France) has been assessed by testing custom-made tissue-mimicking ultrasound phantoms that have comparable shear modulus ranges as human muscles of interest. Reproducibility of shear-wave measurement has been assessed for fusiform and pennate muscles, such as the biceps brachii and the gastrocnemius muscles. The effect of non-contractile tissues on shear-wave measurement has also been examined. Despite the ambitious application of physics in homogeneous and isotropic materials to heterogeneous and anisotropic muscle tissues, we have often observed reasonable responses in various muscles and conditions, in general, when spatial average of shear-wave propagation velocity is used. At the same time, the technology appears to have various limitations. In this talk, we plan to introduce and discuss our explorations into trying to understand the utility of shear-wave elastography for better understanding mechanical properties and activity of individual human muscles that may be altered acutely with various targeted interventions, including stretching, dry-needling, and inter-structural release procedures.

O12 SPORTS BIOMECHANICS

O12.1 Influence of ankle taping and drop landing height on time of muscular pre-activation

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Old Dominion University

The Tau principle describes the interaction of visual information coupled in a feedback mechanism whereby optic flow guides motor processes. This coupling would be representative of the influence of perceived information on motor control. Investigations have been conducted on aspects of action-perception coupling in visual tracking, playing music, and sport, utilizing a number of research paradigms. Prophylactic ankle taping is widely used for the prevention and treatment of ankle sprains through its restrictive properties at the joint. While taping restricts movement, it also reduces sensory perception, and that impact on the Tau principle is not well understood. Therefore, the aim of this study was to investigate the influence of optic flow on EMG pre-activation time during a drop landing from varied heights during taped and un-taped ankle conditions. Twenty recreationally active females with no history of orthopedic injury to the lower limb participated in the study. Participants were assessed on two occasions during a drop landing protocol from heights of 30, 45, and 60 cm during one taped (dominant) ankle session and non-taped (control) session. Four EMG sensors were placed on the tibialis anterior (TA), medial gastrocnemius (MG), rectus femoris (RF), and biceps femoris (BF) on the dominant limb during the drop landings. The onset of EMG activity, defined as 10 standard deviations from mean relaxed baseline activation, during decent would represent the time of pre-activation. Participants completed a baseline maximal isometric contraction to normalize EMG values. Baseline control landings were assessed, followed by either a taped or control condition, with one last set of landings after an exercise protocol which consisted of a 15 minute run at a self-selected pace with a two-minute lateral shuffle cooldown. EMG data was filtered using a 4th order Butterworth filter with a high pass cutoff value of 30 Hz. Initial data from TA EMG indicate a later time of pre-activation during the taped condition in anticipation of the ground impact when compared to the control, and was exhibited across all three heights. Time of pre-activation remained the same between the initial taping, and after the exercise protocol at the 60-cm height, while in the 30 and 45 cm heights, pre-activation time returned similar to baseline and control. Furthermore, mean EMG RMS values indicate levels of activation relative to landing heights, where 60 cm showed the highest TA activation. Perhaps, the delayed activation of muscles is essential for proper landing mechanics due to ankle taping, and its possible relation to performance decline or injury risk should be considered by researchers and clinicians.

O12.2 Ankle Stability - Which muscles are essential for stabilization

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Background and Aim: Ankle stability is a critical factor for gait function. When ankle stability is compromised, individuals may have an increased chance of injury or re-injury. Researchers/clinicians typically focus on ligaments and other passive structures that stabilize the ankle. In comparison, we know little about how muscles that cross the ankle contribute to its stability. In the context of this research, stability is defined as the passive and active force contributions to maintain static equilibrium. Using a model we developed for the ankle joint, our purpose was to assess the relative contribution of each muscle to the stability of the ankle.

Methods: 12 participants performed isometric contractions at 25 and 75% of their maximum voluntary torque effort for dorsiflexion, plantarflexion, inversion, or eversion in a Biodex dynamometer. Each participant performed these contractions with their foot positioned in 90 and 120 degrees plantarflexion. Based on initial theoretical calculations using our model of the ankle joint (Figure 1), we found 97% of ankle stability was accounted for by 9 of the 12 muscles that cross the ankle. To experimentally test our model predictions, surface electromyography was used to measure muscle activity from the tibialis anterior, gastrocnemius medialis, gastrocnemius lateralis, and soleus muscles. Fine wire EMG was used to assess the muscle activity of the tibialis posterior, extensor digitorum longus, peroneus longus, brevis, and tertius. We quantified ankle joint stability using an EMG-driven model of muscle force and subsequently determined how individual muscles contribute to overall ankle stability[1].

Results: The model predictions suggested that when having the muscle fully activated, plantarflexion/dorsiflexion stability would be dominated by the soleus (45%) muscle followed by the gastrocnemius muscles (24%), tibialis anterior (11%), tibialis posterior (9%), and extensor digitorum longus (5%). Preliminary analysis (n=6) of the experimental results suggest these muscles are important contributors to plantarflexion/dorsiflexion stability with the soleus (49%) being the main contributor followed by the tibialis anterior (22%), extensor digitorum longus (11%), gastrocnemius muscles (6%), and tibialis posterior (2%). These results pertain to the 25 and 75% contractions. Further analyses will uncover the role of each of the muscles depending on posture and the direction (i.e., inversion/eversion vs. plantarflexion/dorsiflexion) isometric contraction.

Conclusions: Ankle stability is typically understood in terms of how ligaments and passive structures support the ankle. This research highlights, in addition to these passive structures, which muscles are responsible for stabilizing the ankle joint. This information can help guide rehabilitation programs aimed at improving joint stability after an ankle injury.

1. Potvin & Brown (2005), J. Biomech., 35, 973-80.

O12.3 Reactive Agility Responses in Collegiate Tennis Players after 8-Weeks Whole Body Vibration Training

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BACKGROUND AND AIM: It is known that Whole Body Vibration (WBV) training might increase intra-muscular and inter-muscular coordination of the muscles and consequently, could improve some motoric features such as strength, speed, agility by making an impact on especially muscle spindles and golgi tendon organs (Albasini et al., 2010). Many studies in the literature focused on the effects of WBV training on muscle strength (Roelants et al., 2006; Wang et al., 2014), repeated sprint performance (Ronnestad and Ellefsen, 2011), flexibility (Cochrane and Stannard, 2005; Fagnani et al., 2006) and reported positive results related to WBV after training period. Even though WBV training contributes different motoric features, it is unclear and there is no consistent evidence about reactive agility performance. Therefore, the aim of this research was to assess the effect of WBV training on reactive agility (with and without racket).

Methods: 19 university level tennis players participated in the research voluntarily. Nine of these volunteers comprised the training group (age: 21,55±2,69 year, training age: 32,44±13,42 month, height: 171,44±8,06 cm, body mass: 63,66±12,62 kg) and 10 of them were the control group (age: 21,40±2,59 year, training age: 37,30±21,74 month, height: 172,10±9,82 cm body mass: 64,90±11,22 kg). Reactive agility tests were measured by electronic timing system (Smart Speed; Fusion Sport Pty, Ltd, Brisbane, Queensland, Australia). Four timing gates placed on the court as a Y shape and as soon as the player passed from the second gate right or left gate were blinking randomly. Total time and reaction time have been calculated for both with racket and without racket conditions. After the measurement procedure, training group practiced WBV training on a platform (Compex, Winplate, Canada) which has incrementally increasing performance levels for eight weeks from 1 to 4, three times a week and one level up for every fortnight. The recommendations given by Kleinöder (2009) has been followed during the training period. Since the data showed a normal distribution a Two-way Anova was used for each group to analyze and see if there are any differences between pre and posttest values of designated independent variables. Statistical significance was taken as $p<0.05$ in all test.

Results: After 8 weeks WBV training, training group showed signs of improvement on reactive agility (with and without racket) with varied percentages but none of these improvements were statistically significant (with racket; total: $F=5.13$ $p=0.053$ reaction: $F=3.24$ $p=0.109$ without racket; total: $F=4.41$ $p=0.069$ reaction: $F=3.38$ $p=0.103$).

Conclusions: Results shows that 8 weeks WBV training, which is performed three times a week before the regular tennis training sessions, positively affected reactive agility performance of tennis players. Our results also indicated that especially total time of the training group improved after WBV intervention.

O12.4 Torque sharing between hamstring muscle heads is individual-specific and is related to motor performance

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BACKGROUND AND AIM: As the number of muscles exceeds the dimensionality of most tasks, many different coordination strategies are theoretically possible to achieve the same goal. As such, it is possible that each individual has unique muscle coordination strategies that will have specific mechanical effects on their musculoskeletal system and subsequent motor performance. This study aimed i) to describe individual torque sharing strategies between the heads of the hamstrings and ii) to determine whether the imbalance of activation between the muscle heads affect the endurance performance during a sustained submaximal task.

Methods: First, volume and moment arm of semitendinosus (ST), semimembranosus (SM) and biceps femoris (BF) were determined from segmented Magnetic Resonance Images (MRI) collected on a total of 22 healthy volunteers. Fascicle length of BF (short and long heads) and SM were measured with panoramic ultrasound. Because ST is fusiform, muscle-tendon length from MRI was considered as fascicle length. Then, participants were seated on an isokinetic dynamometer. Hip and knee angle were fixed at 90° (0°, neutral position) and 45° (0°, full extension), respectively. After a standardized warm-up and 3 MVC, participants sustained three 10-s isometric contraction at 20% of MVC. During these tasks, electromyographic (EMG) activity was recorded through surface electrodes placed over the ST, SM and BF. The torque produced by each muscle head was estimated using physiological cross-sectional area, moment arm and activation amplitude. The ratio of torque between the hamstring muscles was calculated as the torque of one muscle divided by the sum of all three muscles. The imbalance of activation among the three muscle heads was determined as the standard deviation of the RMS EMG amplitude measured during the 10-s submaximal isometric tasks. After a 5-min rest period, participants performed an isometric torque-matched flexion at 20% of MVC until task failure.

Results: Although a main effect of muscle ($P<0.001$) on the torque production, we did not observe neither a main effect of leg ($P=0.34$) nor an interaction muscle × leg ($P=0.53$). Torque produced by ST (7.0 ± 3.5 %) was lower than BF (45.7 ± 32.9%; $P<0.001$) and SM (55.1 ± 21.9%; $P<0.001$). Specifically, torque ratio ranges from 20.2 to 54.8%, 28.3 to 63.7% and 9.1 to 39.9% for BF/Hams, SM/Hams and ST/Hams, respectively. There was a significant negative correlation between the time to exhaustion and the standard deviation of the activation level calculated among the three muscle heads ($r=0.52$ [$P<0.001$] and $r=0.42$ [$P=0.011$] for dominant and non-dominant leg, respectively).

Conclusions: Our findings showed a large interindividual variability in torque sharing strategies between hamstring muscles. These results support the hypothesis that coordination vary greatly among individuals and have functional consequences, i.e. larger the imbalance of activation across muscle heads, lower the muscle endurance

O12.5 Sub-Optimal Hydration Impairs Muscle Contraction Speed in Forearm Muscles.

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BACKGROUND AND AIM: Athletes, particularly those in weight category sports, may choose to reduce their body mass through reduced fluid intake prior to competition. The negative effects of decreased hydration levels, on endurance performance, have been well described. However, there is less understanding around the impact of sub-optimal hydration on strength and power production. We aimed to examine the effects of reduced hydration status on handgrip strength and acute fatigability; we also examined the contractile response of the forearm muscles to percutaneous electrical stimulation.

Methods: Twelve healthy active males completed a cross-over design, incorporating normal (euhydrated) and sub-optimal (hypohydrated) conditions. Hydration status was assessed through urine osmolality, body mass and bioelectrical impedance. Muscle stiffness and contraction speed were assessed from brachioradialis (BR) and flexor digitorum profundus (FDP) using tensiomyography (TMG). Maximal voluntary handgrip strength (MVC) was recorded, and electromyography (EMG) of BR was captured during a submaximal isometric handgrip. Participants then completed 10x 10 repetitions of wrist-flexion exercise using a load equivalent to predicted 10-repetition maximum, with MVC recorded at the end of each set. EMG and TMG assessments were next repeated, exactly as before the exercise.

Results: Body mass (80.2 ± 11.2kg vs. 82.0 ± 11.7kg) and bioelectrical impedance (27.8 ± 3.8% vs. 28.7 ± 3.7%) were significantly lower, and urine osmolality was significantly higher (910.8 ± 54.4mOsomls/kgH2O vs. 662.5 ± 208.3mOsmols/kgH2O) in the hypohydrated condition. MVC was significantly reduced following completion of exercise, in both euhydrated (39.6 ± 14.8kg vs. 47.3 ± 13.3kg) and hypohydrated (39.7 ± 12.9kg vs. 45.2 ± 15.0kg) conditions. Normalised EMG amplitude was significantly higher post-exercise in both euhydrated (20.1 ± 6.1% vs. 18.1 ± 7.3%) and hypohydrated (17.6 ± 5.9% vs. 16.4 ± 7.5%) conditions. Muscle contraction time in hypohydrated condition was longer (i.e. slower) pre-exercise for BR (22.6 ± 12.1ms vs. 20.5 ± 8.2ms) and FDP (18.4 ± 1.2ms vs. 17.7± 2.0ms), and post-exercise ([BR] 20.45±3.14ms vs. 19.75±11.45ms and [FDP] 17.66±1.96ms vs. 16.46±2.35ms). Muscle stiffness was unaffected by condition or by exercise.

Conclusions: Sub-optimal hydration was associated with a lengthening of muscle contraction time, in both rested and fatigued state. However both strength and fatigability were similar regardless of hydration status. Therefore it seems that, despite impaired muscle contraction speed, force production and neuromuscular recruitment are not acutely affected by reducing fluid intake.

O12.6 Location of innervation zone on pectoralis major muscle and its shift during the bench press exercise

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AIM: During bench press exercise, attention is often focused on the effect of exercise variants, such as trunk inclination [1]. However, regarding this exercise variant, contradictory findings on the pattern of pectoralis major (PM) activation have been reported [1,2]. Whether such discrepancies indicate different patterns of PM activation is possibly attributable to non-physiological limitations in surface electromyography, such as the innervation zone (IZ) displacement during dynamic contractions, remains an open issue. Once the region above IZ is markedly affected by a small EMG amplitude, its displacement has been indeed quantified for lower and upper limbs [3,4]. Here we therefore collected EMGs from multiple PM regions to quantify: i) the IZ position in different, cranio-caudal regions within PM and ii) how much IZ position changes during the bench press exercise.

Methods: While laying comfortably on a flat bench in supine position, eleven healthy, male subjects were instructed to perform four isometric contractions against a fixed barbell in two different conditions: (i) elbow joint at 0° (elbow fully extended); (ii) elbow joint flexed at 100°. Each contraction lasted 10 s with a rest-in-period of 3 min. Since PM covers a broad area, EMGs were detected from four PM regions equally spaced along the sternum length (cranial, centro-cranial, centro-caudal, caudal). Specifically, a dry array of 16 electrodes was centred at each region with the first electrode placed as close as possible to the sternum. While the array orientation was slightly changed, EMGs were visually inspected until the propagation of action potentials could be clearly observed. The IZ position was defined as the position of the channel located between channels providing EMGs with clear phase opposition [3]. The amount of IZ shift was therefore computed as the difference between the IZ position identified for both, elbow joint angles and for each of the four detection sites. The ANOVA two-way test was applied to compare the IZ location between the two elbow joint positions for the four PM sites considered.

Results: From 82 out of 88 EMGs analysed (4 detection sites x 2 elbow angles x 11 participants), the IZ position could be clearly identified. Furthermore, the Tukey's post-hoc test reveals the IZ location of PM muscle significantly changes with the elbow flexion. For all PM detection sites considered, the IZ laterally shifts around 1.60 ± 0.21 cm with the elbow joint flexion during the bench press exercise ($P < 0.03$ for all cases).

Conclusion: Our protocol could assist the electrodes placement on PM muscle during research involving dynamic contractions. Additionally, our findings revealed that the IZ location and its displacement should be considered in investigations on the pattern of PM activation during the bench press exercise.

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O13 CLINICAL NEUROMECHANICS

O13.1 The effects of forearm rotation on forearm muscle recruitment patterns during dynamic wrist flexion and extension contractions using a haptic wrist robot

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Background and Aim: The wrist extensor muscles are primarily responsible for providing stability to the wrist joint complex. They often demonstrate higher levels of muscle activity than the wrist flexors across an array of forearm and wrist postures, which makes the extensors susceptible to chronic overuse injuries. Current research has examined forearm muscle recruitment under mostly isometric conditions, with little focus given to dynamic contractions under controlled conditions.

Methods: Surface electromyography (EMG) was recorded from eight muscles on the right upper extremity: flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), extensor digitorum (ED), biceps brachii (BB) and triceps brachii (TB). Participants were seated with their right arm supported by a three degrees of freedom wrist manipulandum (WristBot, Genoa, Italy) with hand firmly grasping its handle. The robotic device exerted forces through the handle, in either a flexion or extension direction. ±40° of wrist flexion/extension was performed in three forearm positions; 1) 30° supination, 2) neutral, and 3) 30° pronation. Force was applied in two directions (flexion or extension), resulting in six randomized conditions. For all conditions, a force of 15% of maximum wrist extension was produced by the robot. Six repetitions, consisting of both a concentric and eccentric phase, was performed for each condition. To control for angular velocity, the device was interfaced with a virtual reality environment and handle position was displayed on a computer monitor in which participants tracked a moving target. The robot compensated for weight and inertia during movements. Muscle activity was linear enveloped (3Hz Butterworth cut-off), normalized to muscle-specific maximal voluntary contractions (MVC) and angular position determined concentric and eccentric movements.

Results: The wrist extensors were significantly more active than the wrist flexors, with average muscle activity at, or exceeding 10% of MVC across all conditions. Interestingly, the wrist extensors demonstrated higher muscle activity than the flexors during wrist flexion conditions (ECR: 9.2% MVC, FCR: 4.3% MVC; ED: 11.5% MVC, FDS: 12.3% MVC; ECU: 11.4% MVC, FCU: 4.5% MVC). During wrist extension, FDS produced the greatest average flexor activity (6.4 - 8.3% MVC). The biceps brachii was influenced by forearm position, with the highest activity obtained in the supinated position (3.0% MVC).

Conclusion: These results suggest that the forearm flexors and extensors have similar roles in both dynamic and isometric conditions (for a neutral wrist posture). The effects of forearm rotation on muscle recruitment patterns could yield insight into muscle roles. Grip force measurements, in addition to wrist forces is an important next step to better understand forearm muscle contributions to dynamic wrist actions.

O13.2 What are the immediate effects of foot orthosis geometry on lower limb EMG activity and foot biomechanics?

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BACKGROUND AND AIM: Foot orthoses can be used in the management of musculoskeletal pathologies by altering external forces applied to the foot, which could consequently alter internal forces generated by muscles. However, little is known about whether systematic changes in foot orthosis geometry result in systematic changes in activation of lower limb muscles. Reduced muscle activation could mean less force through soft tissue which might facilitate healing in pathologies like tibialis posterior tendon dysfunction. The aim of this study was to establish if medial heel wedging and increased medial arch height have effects on EMG of shank muscles and foot and ankle moment/motion.

Methods: Healthy participants (n=17) performed walking trials in standardised shoes with five inserts in a random order: i) a flat inlay and ii) a standard prefabricated Salfordinsole®, and a Salfordinsole® with iii) a 6 mm increase in arch height, iv) an 8 mm increase in medial heel wedging and v) both a 6 mm increase in arch height and an 8 mm increase in heel medial wedging. EMG data from tibialis posterior was captured using a bipolar fine-wire electrode (44 gauge × 100 mm paired-hook wires, Teflon-coated stainless-steel wire) via the posterior approach. Trigno standard surface EMG sensors were used for the tibialis anterior and medial gastrocnemius and Trigno Mini surface EMG sensors for peroneus longus and abductor hallucis. Lower limb kinematic and kinetic data was collected concurrently. The root mean squared (RMS) EMG signal was normalised to the overall peak of the average of the six gait cycles in the flat inlay condition. A repeated measures ANOVA, or non-parametric equivalent, was used to compare peak EMG signals across early and late stance between the 5 orthotic conditions.

Results: Tibialis posterior activity reduced by 9-13% in the wedge conditions and 8-14% in the arch conditions, in early and late stance respectively (all compared to the flat inlay). These were not statistically significantly different with the current sample size. There was no effect of orthotic geometry on other muscles. There was typically a reduction in ankle eversion moment across stance for all orthotic conditions.

Discussion: The findings of this study are similar to that of Murley et al. (1) who found reduced tibialis poster activity in early stance with orthoses vs. shod. The results also support a linear dose-response to extrinsic rearfoot posting in walking in kinematic and kinetic variables without an effect on EMG of other calf muscles (2, 3). The apparent trend, albeit not statistically significant, towards reduction in tibialis posterior activity with both wedging and arch support may be beneficial in treating specific muscle, tendon and joint pathology. Further data is required to fully power this work.

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O13.3 Integrating Neurocognition into Clinical Single-Leg Hop Tests

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INTRODUCTION: Functional testing to determine return-to-play readiness has typically only measured physical capability. However, many lower extremity injuries occur within a dynamic sporting environment taxing physical and neurocognitive abilities. Four foundational hop tests have existed in the literature since the 1990s with little modification. Integrating neurocognitive elements during single-leg hop tests mirror more sport-specific challenges by adding reactive components that may be more ecologically valid. The purpose of this study was to determine the relationship between the four foundational single-leg hop tests and the respective neurocognitive single-leg hop test.

Methods: Twenty-two college-aged participants (9 Male, 13 Female, 20.9±2.5 years, 171.2±11.7 cm, 70.3±11.0 kg) were recruited. All participants were healthy and active for three days a week for at least one hour. Participants performed four single-leg hop tests (single-leg hop, single-leg crossover hop, single-leg triple hop, and single-leg 6-meter hop) in the traditional method and under neurocognitive challenge in a randomized order. The neurocognitive conditions were implemented using the FitLight system (Fitlight Sports Corp., Aurora, Ontario) to add cognitive elements and have been found to have good to excellent reliability (ICC=.0.87-0.92). Maximum distance was measured for the single-leg hop, single-leg crossover hop, and single-leg triple hop for traditional and neurocognitive conditions. Fastest time was measured for the single-leg 6-meter hop for traditional and neurocognitive conditions. Two repeated measures MANOVAs were conducted for each leg to determine the difference between conditions (traditional and neurocognitive) for the four hop performance dependent variables. Follow up univariate ANOVAs were conducted if the overall MANOVA was significant to determine which dependent variables were significant. Alpha level was set at $p<0.05$.

Results: The repeated measures MANOVA was significant for condition for right and left legs ($p<0.05$). Specifically, the crossover hop (average mean difference 30.12 cm), triple hop (average mean difference 32.53 cm), and 6-meter hop (average mean difference 1.36 s) were statistically different between traditional and neurocognitive conditions ($p<0.05$). However, the single-leg hop was not significantly different between traditional and neurocognitive conditions ($p>0.05$, average mean difference 2.86 cm).

Discussion: Performance degradation was seen on the crossover, triple, and 6-meter hops for the neurocognitive hop condition compared to the traditional condition. However, the single-leg hop showed no degrade in performance likely due to utilizing only a go-stimulus relative to the more difficult conditions (go-no-go). The addition of neurocognitive reactive and/or anticipatory components to simulate more sport specific scenarios may improve functional testing for return to sport.

O13.4 Increased time-pressure results in a less cautious obstacle crossing strategy in subjects with and without simulated visual impairment

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BACKGROUND AND AIMS: Visual impairment causes difficulty in performing everyday tasks and increases the number of falls. Research in temporally unconstrained situations has shown that patients with visual impairment show a more cautious gait and look down to more immediate areas of the ground. However, everyday activities are often performed under time-pressure (e.g., moving quickly to pick up the phone). Therefore, we investigated the effects of time-pressure and visual impairment on the movement kinematics during the performance of an everyday task.

Methods: Subjects were divided into a normal vision (n=14, aged 27±4 years) and blurred vision group (n=14, aged 32±5 years). Subjects were blurred to 1.00 LogMAR. Subjects were required to negotiate a floor-based obstacle (height 10 cm) that was placed in the 8 m travel path. Movement kinematics were assessed throughout the task using a six-camera VICON motion analysis system. The task was performed under high, low, and no time-pressure conditions. High time-pressure was induced by a custom-made timing device that produced an intermittent tone that increased in frequency. This tone forced the subject to perform the task 20% faster than their comfortable walking speed. During the low time-pressure trials, an intermittent tone at a constant frequency was played. After every condition, anxiety and perceived temporal demand were examined using the Spielberger State-Trait Anxiety Inventory and NASA-TLX, respectively. All variables were analysed using a group by condition repeated measures ANOVA.

Results: With increasing time-pressure, subjects experienced more anxiety and a higher perceived temporal demand and performed the task faster (all $p<0.05$). Two out 20 kinematic variables showed an interaction effect; during high vs. low time-pressure, crossing height of the lead toe increased 13% in the blurred vision group and decreased 4% in the normal vision group and step length post-obstacle increased 10% more in the blurred vs. normal vision group (all $p<0.05$). Condition effects between the high vs. low and no time-pressure conditions were; lower obstacle clearance height for the lead toe and trail heel, increased crossing velocity for both feet, a reduced single support phase, increased step and stride length, and the feet were positioned further away from the obstacle prior and after crossing (all $p<0.05$). Group effects showed that visually impaired subjects raised their feet higher to cross the obstacle, decreased the crossing velocity of the lead foot, and increased the time whereby the lead leg was in swing (all $p<0.05$).

Conclusion: Both groups adopted a less cautious strategy under high time-pressure due to the need to walk quicker in the temporally constrained task. However, the visually impaired group demonstrated a more cautious behaviour in all conditions, to reduce the chance of tripping on the obstacle.

O13.5 Spread of Botulinum Toxin Type-A into Non-injected Antagonistic Muscles Affects Their Mechanics against Treatment Aims

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BACKGROUND AND AIM: Botulinum toxin type A (BTX-A) is widely used for local treatment of muscle spasticity. It spreads through fascia and changes the mechanics of neighboring muscles [1-3]. However, BTX-A effects on mechanics of non-injected antagonistic muscles are unknown. Epimuscular myofascial force transmission (EMFT) can also affect mechanics of synergistic as well as antagonistic muscles [4], and its role in BTX-A treated animal should be tested. The aim was to test the following hypotheses posed based on our previous findings, in a rat model: BTX-A injected into the gastrocnemius medialis (GM) and lateralis (GL) (1) decreases forces of also the antagonistic tibialis anterior (TA) and extensor digitorum longus (EDL) muscles, (2) reduces length range of force exertion and (3) increases passive forces of the TA, and (4) changes inter-antagonistic and inter-synergistic EMFT.

METHODS: Two groups of Wistar rats were tested: BTX (n=6, 284 ± 14 g; 0.1 units of BTX-A injected into the GM & GL, each), Control (n=6, 301 ± 29 g; saline injected). Five-days post, TA, EDL, GM-GL, and soleus distal and EDL proximal isometric forces were measured after TA lengthening. Effects of BTX-A on intramuscular connective tissue content of TA and EDL were quantified histologically in separate animal groups: BTX (n=4, 250 ± 36 g), Control (n=4, 285 ± 16 g). 5μm thick muscle sections (cut for every 20μm) were stained with Gomori trichrome.

RESULTS: BTX-A exposure caused forces of all muscles to decrease significantly. TA and EDL active force drops (maximally by 37.3%) confirm inter-compartmental diffusion. Length range of force exertion of the TA did not change, but its passive force increased significantly (by 25%) (Fig 1A). Intramuscular connective tissue content of the TA and EDL increased (by 54% and 21%, respectively). Calf muscles' forces were not affected by TA length changes for both groups indicating lacking inter-antagonistic EMFT. However, BTX-A altered EDL proximo-distal force differences hence, inter-synergistic EMFT (Fig 1B). The effects shown on the antagonistic muscles agree with our previous findings shown after BTX-A exposure within the same compartment.

CONCLUSIONS: A major novel finding is that BTX-A does affect mechanics of non-injected antagonistic muscles, and via inter-compartmental diffusion, in the lack of EMFT. The effects indicating a stiffer muscle exposed to BTX-A with no length range increase contradict some treatment aims, which requires clinical testing.

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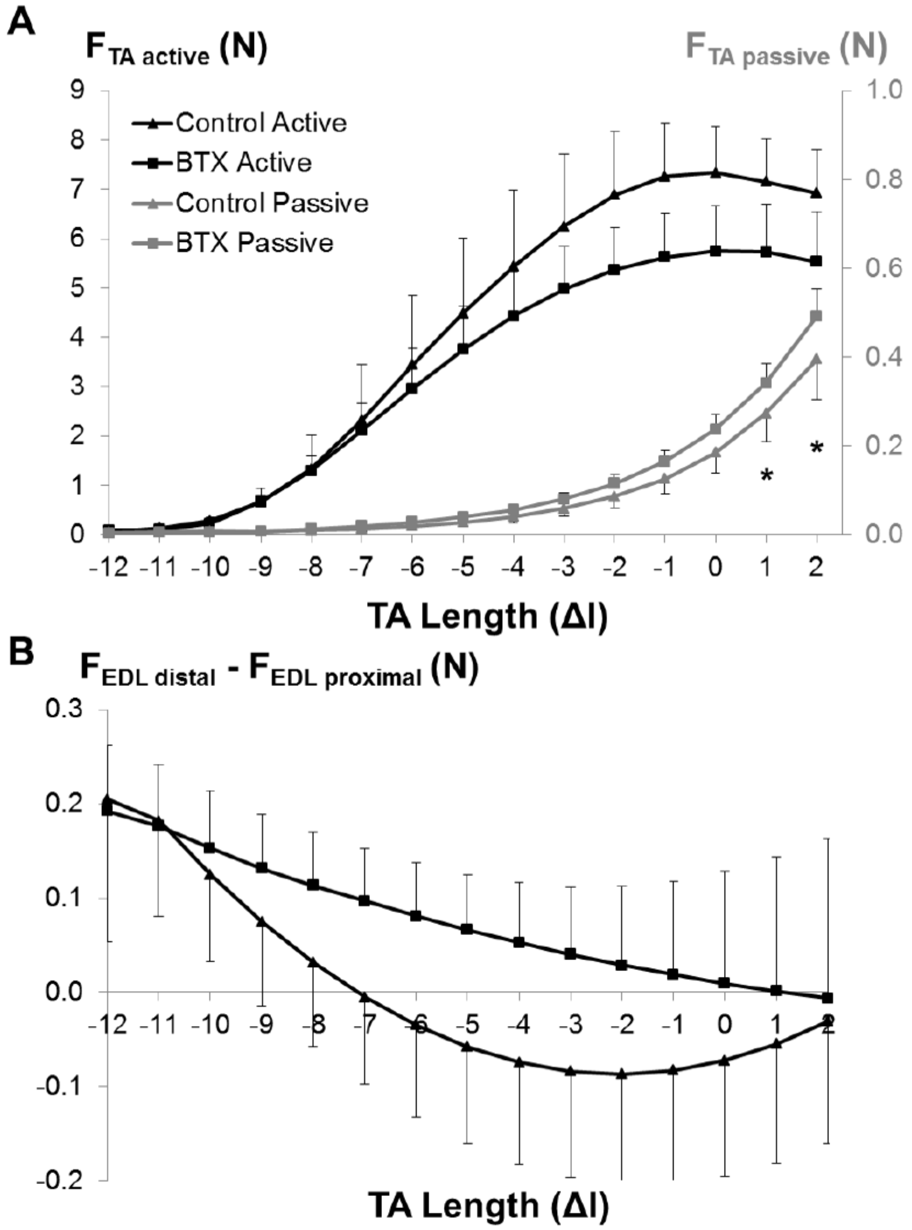

Figure A) Active and passive length-force characteristics of non-injected antagonist tibialis anterior (TA) muscle. **B)** The difference between distal and proximal active forces of EDL ($F_{EDL\ distal} - F_{EDL\ proximal}$) as a function of increasing TA muscle-tendon length. Isometric muscle forces are shown as mean and standard deviation values for the Control and BTX groups. TA muscle-tendon complex length is expressed as a deviation from its optimum length (Δl = 0). * indicates the lenghts where passive forces are significantly different.

O13.6 Lumbar posture and muscle recruitment during repetitive manual handling in young and older males.

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BACKGROUND AND AIM: Epidemiological evidence suggests an association between repetitive lifting and an increased risk of low back injury. Repetitive lifting has been shown to lead paraspinal muscle fatigue, increased lumbar flexion and increased loading on the posterior passive structures of the spine. In an ageing work force, the risk of injury may be magnified due to reduced physiological capacity of older workers. However, the lifting strategies and physiological responses of older workers undertaking repetitive lifting is not well understood. This study investigated the lumbar kinematics and kinetics, and muscle activity in two different age groups (younger versus older males) when performing a repetitive lifting and lowering task.

Methods: Fourteen healthy young (mean age = 24.4 years) and fourteen older (mean age = 47.2 years) adult males repeatedly (10 lifts/min) lifted and lowered a box (13 kg) from a shelf (15 cm above floor) to upright standing for a maximum of twenty minutes. Normalized surface electromyography (EMG) was recorded from five muscle groups (lower erector spinae (LES), upper erector spinae (UES), vastus lateralis (VL), gluteus maximus (GM), biceps femoris (BF)) every minute throughout the lifting task. A nine-camera motion analysis system was used to record three-dimensional (3D) motion in conjunction with 3D ground reaction forces. These were used to record postural kinematics and estimate the bending moment resisted by the posterior passive tissues of the lumbar spine (Doland and Adams, 1994). Paraspinal muscle fatigue was assessed by determining the change in the median frequency (MF) intercept over a static 30 second trunk hold in the Biering-Sørensen position, prior to and immediately after the lifting task.

Results: Older participants adopted a lifting strategy with reduced lumbar flexion, increased knee flexion, and greater UES, LES and VL muscle activity, when compared to the younger age group ($P<0.05$). Despite having increased paraspinal muscle recruitment throughout the task, muscle fatigue was less in older participants, as evidenced by reduced changes in the MF intercept of the UES and LES following the lifting task ($P<0.05$). The bending moment resisted by the passive structures of the lumbar spine increased at a significantly higher rate in younger participants over the course of the lifting task ($P<0.05$).

Conclusion: When repetitive lifting, young, inexperienced males appear to fatigue the local paraspinal muscles at an increased rate and adopt lumbar postures that increase loading on the posterior passive structures of the lumbar spine, compared to an older population. This may put younger workers at increased risk of low back injury, thereby, underlining the importance of training in manual handling when young novice workers first embark on repetitive manual handling occupations.

S8 SYMPOSIUM: NOVEL APPROACHES TO ENHANCE RECOVERY AFTER CENTRAL NERVOUS SYSTEM INJURY

S8.1 Non-invasive brain stimulation

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Plasticity constitutes the basis of behavioural changes as a result of experience. It refers to neural network shaping and re-shaping at the global level and to synaptic contacts remodelling at the local level, either during learning or memory encoding, or as a result of acute or chronic pathological conditions. The 'plastic' brain reorganisation after central nervous system (CNS) lesions has a pivotal role in recovery and rehabilitation of the sensory and motor dysfunction. The physiological basis of plasticity is the long-term potentiation (LTP-) and long-term depression (LTD). The neurophysiological techniques that can induce plasticity or simply modulate cortical excitability or produce interference with normal brain activity and behaviour are known as neuromodulation techniques. It is possible to obtain these effects by applying electrical currents directly to discrete regions of the nervous system (deep brain stimulation, epidural cortical stimulation, epidural spinal cord stimulation, etc.). These techniques are invasive. On the other hand, a number of techniques can obtain neuromodulatory effects in a non-invasive manner (non-invasive brain stimulation-NIBS). The transcranial application of magnetic fields or of electric currents can induce LTP and LTD like after-effects in the human cortex. The intensity, duration and pattern of stimulation lead to different kind of after-effects. We can summarize that, depending on the kind of NIBS used we can increase or decrease the cortical excitability. Synaptic plasticity also depends on the temporal order of the pre- and post-synaptic activity. We know that TMS activates neural (corticospinal) cells transynaptically. From animal model studies, we know that repetitive electrical stimulation can modify the synaptic responses to electrical stimuli. It was easy to think that a repeated TMS application can induce similar effects on the intact human cortex. Moreover, the animal models have been used to test patterned forms of stimulation (more similar to the physiological synaptic modulation). It has been demonstrated that almost all the TMS based non-invasive brain stimulation techniques have effects on the later components of the I-waves. Two exceptions have been reported: 1) cTBS (that is able to suppress the I1-wave); 2) I-wave periodicity stimulation (the effects are not seen in the descending activity/I waves). The tDCS physiological bases are probably different, but the final result is similar. Anodal and cathodal tDCS are able to modulate the later I waves. Moreover, the anodal tDCS probably has effect also by directly increase the excitability of corticospinal axons (effects on D wave have been reported). TMS can be used not only to modulate cortical plasticity but also to study corticospinal pathways, cortical excitability and cortical connectivity. This technique is being used to allow precise diagnosis of neurological disorders and to predict functional outcome after central nervous system injury. Moreover, TMS helps to characterize the different patterns of the excitability changes that exist during the functional recovery after injury.

S8.2 Activity-dependent therapies to facilitate manual dexterity recovery in spinal cord injured rats

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In spite of the anatomical and physiological differences, the spinal cord retains many similarities among mammalian species. Rodents possess certain degree of manual dexterity to manipulate objects, such as the required to reach and grasp, which movements resemble those performed by humans, indicating the utility of the rodent model as an experimental model to study spinal cord function and repair. I will present work showing the impairments in skilled hand function inflicted by injuries to the rat cervical spinal cord, and the recovery achieved after enrolling the animals in intensive task specific rehabilitation and neuromodulation. I will focus on the neurophysiological evaluation of the brain to spinal cord connectivity.

S8.3 Associative neurorehabilitation with Rehab robotics and neuroprosthetics

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Neurological conditions, such as stroke or spinal cord injury, and neurodegenarative conditions, such as Parkinson Disease, are examples of disorders where insults to the Central Nervous System (CNS) result both in cognitive and motor disorders. Brain plasticity, the ability to adapt at cellular and circuit level, is at the basis of most interventions to restore these disorders. In this talk, we will address some of these mechanisms and illustrate them with different technology-based interventions which are associated to the motor status of patients and that seek to promote changes in brain (and CNS) structures, which are consistent with improvements in this conditions.

S8.4 Noninvasive Approaches to Promote Functional Recovery in Humans with Spinal Cord Injury

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Spinal cord injury (SCI) impairs sensorimotor function in muscles below the level of the lesion. Non-invasive approaches suggest that the corticospinal tract represents a target to maximize residual motor output following chronic incomplete SCI. We have used transcranial magnetic stimulation (TMS) over the primary motor cortex to reinforce spinal function using principles of spike-timing dependent plasticity and to mimic the periodicity of descending volleys in the corticospinal tract in humans with and without SCI. This data, along with information about the extent of the injury, provide a new framework for exploring the contribution of the corticospinal tract to recovery of function following SCI.

O14 BACK, NECK & SHOULDER PAIN II

O14.1 Altered lumbar biomechanics in pregnant women during trunk flexion-extension

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BACKGROUND AND AIM: Low back pain is one of the most common complications associated to pregnancy. Pain typically intensifies with certain positions, especially during trunk flexion. Despite its high prevalence, the aetiology of pregnancy-associated low back pain remains unknown. It is thought to be caused by a combination of biomechanical and hormonal factors. In the general population, there is a close relationship between trunk flexion-extension movement and the genesis of back pain. In fact, patients with low back pain change their patterns of motion and activation of the extensor muscles during trunk flexion-extension. However, there is no evidence on lumbar muscle and motion behavior in pregnant women. This study analyzes lumbar spine motion and the activation pattern of the lumbar erector spinae muscle during trunk flexion-extension movements in healthy pregnant women. The hypothesis is that the biomechanical and hormonal changes that occur during pregnancy alter the kinematics of the lumbar region and the activation patterns of the erector spinae muscles.

Methods: The study involved 34 nulliparous women (control group) and 34 pregnant women in the third trimester (week 36 ± 1). We recorded the position of the lumbar spine in the sagittal plane, and the EMG activity of the erector spinae muscles, during a flexion-extension task, in both groups, and two months after birth in the group of pregnant women. EMG activity was expressed as a percentage of a submaximal reference contraction.

Results: A decrease in lumbar maximum flexion, the percentage of lumbar flexion during forward bending and the time keeping maximum levels of lumbar flexion was observed in the group of pregnant women, relative to the control and postpartum groups. Greater erector spinae activation was also observed during forward bending and eccentric contraction in pregnant women, as well as a shortened erector spinae myoelectric silence during flexion.

Conclusions: Pregnant women show adaptations in their patterns of lumbar motion and erector spinae activity during trunk flexion-extension. Erector spinae increases its activity and shortens its relaxation time during flexion. These changes could be related to biomechanical protection mechanisms against the increase on abdominal mass and the increased ligamentous distensibility caused by relaxin.

O14.2 Lumbar kinematics and fear-avoidance beliefs in relation to disability and workability in patients with low back pain. A longitudinal study.

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Background: Low back pain (LBP) is the leading cause of disability, and may affect physical function and ability to work. Impaired lumbar movement has been associated with LBP. Previous research found that people with LBP have reduced range of motion (ROM) and velocity in spinal movement, and kinematics has been used to differentiate LBP patients from healthy controls. However, there is limited knowledge on the longitudinal associations between kinematic measures and physical- and work related disability due to LBP. According to the fear-avoidance model, chronic pain may develop as result of avoidance behavior, and function of the spine may be restricted by patients' fear of movement. The role of fear-avoidance beliefs (FAB) and kinematics in longitudinal associations to disability and workability in patients with LBP, is poorly understood. Aim: The aim of this study was to investigate the longitudinal associations between spinal kinematics and FAB with disability and workability in patients with LBP, and, secondary, to explore associations between kinematics and FAB.

Method: The current study was an observational study of 44 patients with non-specific LBP receiving physiotherapy treatment. Kinematic data, FAB, and self-reported disability and workability were collected at baseline, 3 and 9 months follow-up. Kinematic data during standing flexion and extension were recorded by motion sensors attached to the skin over the spinous processes of T6, T12 and S2, using a Liberty motion tracker system. The system identified ROM and peak velocity of the movement. Flexion and extension were separated in start, mid, and end segments based on the person's ROM and were analyzed separately. Within-person effects over time were calculated by fixed effects linear regression analyses, using all available data for each person.

Results: Out of the 44 included participants, 28 were female, and mean age was 42.8, range 15-74. Forty patients (91 %) participated at 3 months and 30 (68 %) at 9 months. Overall, peak velocity increased from baseline to 3 and 9 months follow-up. Changes in velocity occurred primarily within 3 months. ROM increased from baseline to 3 months by 10.3° (95% CI 1.4 to 19.2). Longitudinal analyses show that increased ROM were weakly associated with less disability (-0.14, 95% CI -0.22 to -0.06). Peak velocity were not associated with either disability or workability in analyses adjusted for ROM. Increase in the FAB subscale on physical activity were accompanied by higher disability (1.50, 95% CI 0.51 to 2.49), and increase in the FAB subscale of work by lower workability (-0.37, 95% CI -0.68 to -0.05). Peak velocity in descending phase showed weak associations with FAB subscale on physical activity.

Conclusion: Of the kinematic measures, only ROM were related to self-reported disability and workability. Further, the findings indicate that FAB is related to disability, workability and to angular velocity; however, the clinical importance is not clear.

Table 1. Longitudinal within person associations (β coefficients) between kinematic and fear-avoidance with disability (ODI) and workability. Measures of peak velocity were divided in 3 identical segments for descending and ascending phase: start-, middle-, and end segments. Measured at baseline, 3 and 9 months.

	Disability (0-100)	Workability (0-10)
Max ROM from neutral position (°)	-0.14 (-0.22 to -0.06)	0.01 (-0.01 to 0.03)
Peak velocity descending phase		
Start segment (°/s)±	-0.08 (-0.18 to 0.02)	0.00 (-0.02 to 0.02)
Middle segment (°/s)±	-0.05 (-0.16 to 0.05)	-0.01 (-0.03 to 0.01)
End segment (°/s)±	-0.04 (-0.14 to 0.06)	-0.01 (-0.03 to 0.01)
Peak velocity ascending phase		
Start segment (°/s)±	0.01 (-0.08 to 0.10)	-0.01 (-0.03 to 0.01)
Middle segment (°/s)±	0.00 (-0.10 to 0.10)	-0.01 (-0.03 to 0.01)
End segment (°/s)±	-0.03 (-0.11 to 0.06)	-0.01 (-0.03 to 0.01)
FABQ-PA,† (one unit represents 10%)	1.50 (0.51 to 2.49)	-0.11 (-0.30 to 0.08)
FABQ-W,† (one unit represents 10%)	1.22 (-0.46 to 2.90)	-0.37 (-0.68 to -0.05)

± Adjusted for ROM
† Both subscales of FABQ were transformed to relative score of max score, and one unit increase in FABQ represent 10 % points.
ODI, Oswestry Disability Index; ROM, Range of movement; FABQ-PA, Fear-avoidance Beliefs Questionnaire for Physical activity; FABQ-W, Fear-avoidance Beliefs Questionnaire for Work.

O14.3 Shear wave elastography reveals differences in lumbar erector spinae muscle stiffness in individuals with low back pain

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BACKGROUND AND AIM: Shear wave elastography (SWE) permits non-invasive quantification of muscle stiffness. Changes in lumbar paraspinal muscle activity are well documented in people with chronic non-specific low back pain (CNSLBP), yet no study has investigated active paraspinal muscular stiffness or the contraction ratio, that is, the change from passive to active muscular stiffness. The aim of this study was to compare muscular stiffness of erector spinae (ES) and multifidus at rest and during isometric back extension (active muscular stiffness), and the contraction ratio of ES between CNSLBP and asymptomatic participants. A secondary aim was to investigate the association between muscular stiffness and the contraction ratio for all participants, and the association between the degree of muscular stiffness and pain intensity, disability and kinesiophobia in participants with CNSLBP.

Methods: 15 participants with CNSLBP (7 male; age 29.4 ±10.8 years) and 15 asymptomatic control participants (8 men; age: 26.5 ±4.9 years) were included. The study was approved by the University of Birmingham Ethics Committee. Participants with CNSLBP had a mean pain intensity of 2.2 ±1.6 on a numerical rating scale (NRS), perceived disability of 12.7 ±6.3% on the Oswestry Disability Index (ODI) and a level of kinesiophobia of 34.4 ±3.1 on the Tampa Scale of Kinesiophobia (TSK). With the participant in prone, passive muscular stiffness of ES and multifidus were measured (SWE LOGIQ S8 GE Healthcare, USA) bilaterally at the level of the third lumbar vertebra. Active muscular stiffness was measured for ES only during back extension, a position akin to the Ito test. For each position, muscle and side, the mean of 2 acquisitions (2x9 frames values) was calculated to obtain the shear modulus as a measure of muscular stiffness.

Results: Participants with CNSLBP had greater passive muscular stiffness of the ES compared to the control group (CNSLBP: 10.1 ±4.2 kPa; controls: 6.8 ±1.7 kPa, $p<0.01$), but there was no difference between groups for the multifidus (CNSLBP: 14.41 ±2.62 kPa; controls: 15.4 ±2.77 kPa, $p=0.324$). Moreover, there was no significant difference between groups for ES active stiffness (CNSLBP: 14.32 ±3.97 kPa; controls: 16.66 ±5.00 kPa, $p=0.166$). The contraction ratio was significantly lower for the CNSLBP group (CNSLBP: 4.2 ±4.3 kPa; controls: 9.8 ±5.5 kPa, $p<0.01$). Across both groups, the higher passive muscular stiffness of ES was associated with lower contraction ratios ($r= -0.58$, $p<0.01$), and the higher passive muscular stiffness of multifidus was associated with higher active ES muscular stiffness and a higher ES contraction ratio ($r=0.42$ and $r=0.42$ respectively, $p<0.05$). No significant correlations were identified between active or passive muscular stiffness and NRS, ODI and TSK for the CNSLBP group.

Conclusions: ES passive muscular stiffness is higher in people with CNSLBP, but the extent of muscular stiffness is not associated with pain intensity, disability or kinesiophobia. Increased passive muscle stiffness may have relevance for persistent CNSLBP and this should be explored in future work. Further studies are also needed to appreciate the mechanisms associated with a change in muscle stiffness in people with CNSLBP.

O14.4 Eight weeks of training with EMG-biofeedback and the effect on pain and function in patients with subacromial impingement - a randomised controlled trial

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Introduction: Subacromial impingement syndrome (SIS) is the most common shoulder disorder, and electromyography (EMG) biofeedback seems promising in teaching these patients a functional healthy muscle activity pattern. The effect of EMG biofeedback has never been studied in a randomised controlled trial. The aim was to investigate the effect of EMG-biofeedback supervised neuromuscular shoulder exercise program (BIONEX) on shoulder pain and function in patients with SIS compared with the same shoulder exercise program without EMG-biofeedback (NEX).

Materials and methods: Forty-nine patients with SIS (25 women, aged 19-67 years) were randomised to either BIONEX (n=26) or NEX (n=23). The intervention included eight weeks of scapula stabilising exercises with or without supervised EMG-biofeedback. Outcomes were self-reported shoulder pain (Numeric Pain Rating Scale, NPRS), function (Disability of Arm Shoulder and Hand, DASH), Oxford Shoulder score, OSS), and measured shoulder function (surface EMG on the upper trapezius (UT), lower trapezius (LT) and serratus anterior (SA) muscles). EMG was measured during three voluntary arm elevation and lowering tasks with 0 kg, 1 kg and 3 kg, respectively, and expressed as % of maximum voluntary EMG (%MVE), ratios of %MVE (UT/LT, UT/SA, LT/SA) and onset time in msec (UT-LT, UT-SA, LT-SA).

Results: Compliance in supervised visits was 86% and 88% with BIONEX and NEX respectively, with no significant group difference. BIONEX showed no additional positive effect on shoulder pain (0.20; p=0.73), or self-reported shoulder function (DASH or OSS) when compared with NEX. Neither was there any significant group difference in changed %MVE, EMG ratio or onset time. However, both groups showed significantly reduced pain intensity (NPRS within the past 7 days, NPRS now), improved self-reported function (DASH total, DASH sport, OSS) from baseline to follow up, and for BIONEX also at NPRS within the past 24 hours. For the EMG variables significantly positive within group changes were seen in BIONEX, regarding reduced UT in elevation, increased SA during lowering, and reduced onset time for UT-LT. For NEX a positive within group change was only seen as decreased onset time in UT-SA.

Conclusion: While no superior effect of exercises with EMG-biofeedback was found on shoulder pain, self-reported and measured shoulder function, a more consistent pattern of statistically significant (and on average clinically relevant) within-group improvements from baseline to follow up was seen in the BIONEX group. However, due to the positive effects in both groups an individualized approach of exercise therapy for SIS patients is recommended.

O15 MOTOR CONTROL III

O15.1 Each individual has unique muscle activation signatures

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BACKGROUND AND AIM: Each individual differs from any other. Biometrics took advantages of these differences such that algorithms have been developed to recognise physical characteristics such as human faces, iris, or fingerprints. Although a hunch that movement features vary from an individual to another, the vast majority of studies on human movement report values averaged from a group of individuals, making it impossible to appreciate the difference in the way participants move. In order to prove the existence of individual muscle activation signatures, this study aimed : i) to test the inter-day reliability of muscle activation strategies, ii) to describe the individual variability of activation strategies in a large sample size, iii) to determine the robustness of activation strategies between tasks and iv) to test the ability to classify individuals from their activation patterns measured during pedalling using support vector machines (machine learning approach).

METHOD: Eighty-five healthy volunteers (55 males and 30 females) participated in this study. The first experimental session consisted in a series of single-joint tasks performed with the dominant leg [knee extension at 25% of maximal voluntary contraction (MVC), isometric plantarflexion at 25% of MVC] and multi-joint submaximal tasks [pedalling at 150 Watts and walking on a treadmill at 0.83 m/s, i.e. 3 km/h]. Over the 85 participants, 62 performed a second experimental session 11±12 days after the first session. This second session included both the submaximal knee extension and plantarflexion tasks and aimed to assess the inter-day reliability of the activation strategies during well-controlled tasks. Myoelectrical activity was collected using surface EMG from two muscle groups of the dominant leg: rectus femoris (RF), vastus lateralis (VL) and vastus medialis (VM) for the quadriceps; gastrocnemius medialis (GM), gastrocnemius lateralis (GL), and soleus (SOL) for the triceps surae. The distribution of activation among the synergist muscles was considered through the calculation of the following activation ratios: VL/Quad, VM/Quad, RF/Quad, GM/TS, GL/TS and SOL/TS. A machine learning approach (support vector machines) was used to classify participants based on their time-varying activation patterns measured during pedalling. This approach allowed us to test the uniqueness of the activation patterns.

Results: We observed a fair to excellent reliability of the activation ratios measured during the isometric tasks on 62 participants. It suggests that activation strategies were robust between days. The distribution of activation among the synergist muscles varied greatly between participants. Furthermore, high similarities of activation strategies were observed between tasks ($0.21<r<0.77$). The participant-classification resulted in a classification rate of 98.7% and 98.9% for the cross-validation and the leave-one-out method respectively. It indicates that 1184/1200 and 1187/1200 pedalling cycles were correctly assigned to the corresponding individual.

Conclusion: Overall, this study provides strong evidence for the existence of individual activation strategies. Further work is needed to determine the origin and the potential consequences of these strategies on the musculoskeletal system.

O15.2 Simultaneous and proportional control of combined finger movements

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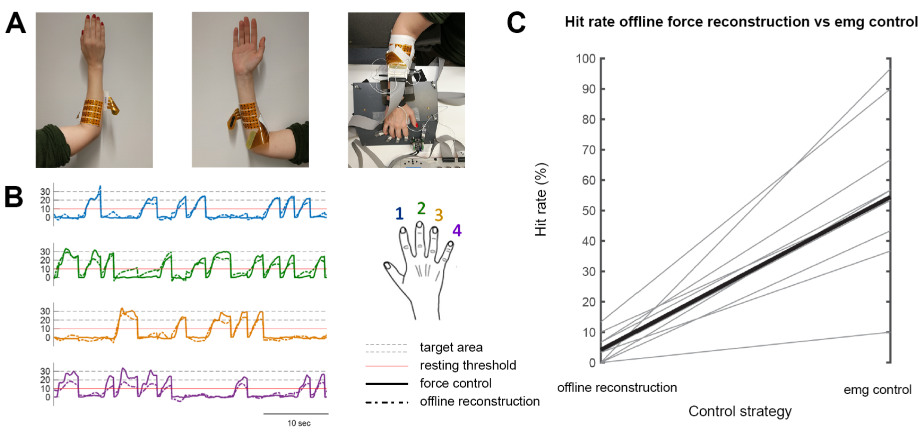
BACKGROUND: Modern myoelectric prostheses allow single finger control in order to mimic the dexterity of the human hand. However, proportional and simultaneous control of individual fingers using surface EMG signals is still to be achieved. Linear superposition in the EMG signals generated during combined finger movements would significantly aid the clinical application of myoelectric finger control by allowing the training data to be reduced to the activation of individual fingers. This study aims to investigate whether participants are able to adapt to a linear controller trained on single finger data.

Methods: Twelve able-bodied participants performed an online myoelectric control experiment including combined isometric flections of the index, middle, ring, and little finger. During the experiment, force and EMG data were collected concurrently. EMG signals were recorded using two 8x8 EMG grids placed over the flexor digitorum superficialis and the extensor digitorum. Training data were restricted to 3 repetitions of single finger presses tracking a trapezoidal force pattern, with the plateau at 25% of maximum voluntary contraction (MVC). These data were used to determine the weights for each EMG channel for online control by linear ridge regression estimating the generated force. The online experiment consisted of 5 trials of 2-finger combination activations where the participant had to hit a target force window between 20% and 30% of the MVC. The dwell time in the target range was 0.5 s and the maximum trial duration was 15 s. The online task was performed twice: once based on force information (force control), and once based on forces estimated through EMG (EMG control).

Results: In the online tests, the hit rate of the targets was 99.7% (± 1.0%) for force control, and 54.4% (± 23.2%) for EMG control. However, the results for the EMG control tasks varied largely among subjects (range 10%-97%). The offline reconstruction of estimated forces based on EMG patterns during the force control tasks showed that only 4.2% (± 4.3%, range 0%-14%) of the EMG patterns during this task would result in hitting the target. All participants showed an improvement in the hit rate from reconstructed forces of the force tasks to the EMG tasks, with an overall significant difference ($p<0.001$).

Conclusion: The difference in hit rate between the offline analysis of the force tasks and the online EMG tasks shows that participants are able to adapt to a linear controller trained on single finger data, even when performing finger combinations. This study reinforces the importance of online validation of myoelectric control strategies, and shows that computationally simple, linear algorithms can be used to estimate complex, articulated movements such as simultaneous and proportional control of 4 fingers.



A. Experimental setup. EMG grids were placed over the flexor digitorum superficialis and the extensor digitorum. The forces were collected with a custom made force device. B. Forces recorded during force control trials and offline reconstruction of forces based on EMG patterns during the force control tasks for all four fingers. C. Offline reconstruction of forces based on EMG patterns of the force control trials result in a low hit rate (lower left corner). The introduction of feedback in the online EMG control trials leads to an improvement in hit rate for all participants (right). The mean over all participants is presented in bold.

O15.3 Violinists' muscular load during violin performance

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BACKGROUND AND AIM: Musicians are fine control performers of the upper extremities and exposed to high repetition in awkward postures. These are potentially harmful factors, associated with musculoskeletal complaints and injuries.[1] Particularly violinists experience high levels of musculoskeletal pain compared to other musicians.[2] In order to prevent injuries among violinists it is important to quantify the workload in the forearm and shoulder muscles while playing and to identify specifically demanding techniques. This study aims to quantify the relative workload for shoulder and forearm muscles during standardized violin playing and the effect of aggravating factors.

Methods: The study was conducted on highly skilled violin players, who were able to perform the required repertoire satisfactorily. The protocol consisted of an A- and E-major scale and a music piece. The A-major scale was played with different techniques: faster playing speed, double fingering (thirds) and vibrato. EMG was recorded bilaterally from the descending part of trapezius and for both forearm muscles: m. flexor digitorum superficialis, m. extensor carpi ulnaris, m. extensor digitorum cummunis and m. extensor carpi radialis. Maximal voluntary contractions were conducted with shoulder elevation and maximal handgrip for normalization of EMG (MVE). One-way repeated ANOVA was used to determine if there were differences between the muscular load during the playing tasks. An alpha level p=0.05 was chosen.

Results: The study population comprised 18 violinists, mean age 42 (±15). Muscle workload is presented as mean level of % MVC. Overall, there was no significant difference between the scales and the music with a relative workload level <15%MVE. The results showed a dynamic load especially for the left forearm muscles (between 8.55-25.1 %MVE) and a general constant workload level for the right forearm muscles around 12%MVE. A significant difference was found for all forearm muscles of the left side when faster speed (p=0.001), thirds (p=0.003) and vibrato (p=0.001) was used compared to the scale without any specific technique. A higher workload level was found for the right forearm muscles when playing thirds (p=0.001), and for one of the extensors and a flexor muscle, when playing with vibrato (p=0.002). Overall, among all the performances faster playing speed for the left forearm muscles showed the highest workload ranging from 8.38 to 42.14 %MVE as shown in fig. 1.

Conclusions: In general, our study demonstrated a dynamic load for the left forearm muscles especially during faster playing speed and a general high level of static muscle activity for the left and right shoulder muscles across all tasks. The use of scales as a standardized work task seems in general to provide a representative estimate for the load during actual playing

References 1. Kaufman-Cohen, Y. et al. (2011). Occup Med (Lond), 61(2), 2. Nyman T, et al. (2007). Am J Ind Med, 50(5):370-376

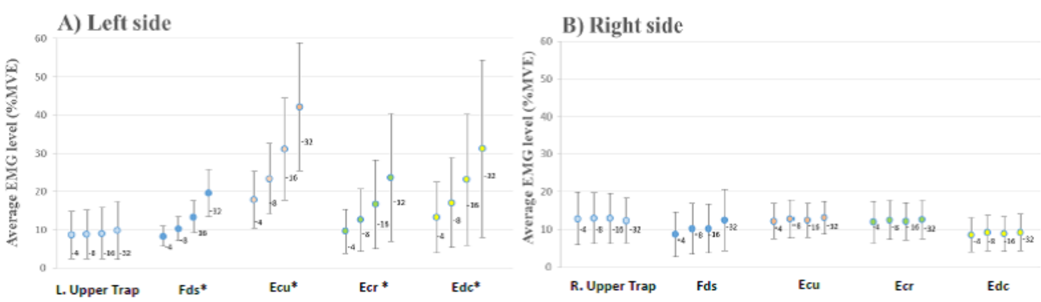

Fig.1: Mean RMS and SD for each muscle in right (A) and left (B) side during the A-major scale played in increasing playing speed from 4th notes to the fastest playing speed 32nd notes. Fds= flexor digitorum superficialis, Ecu= extensor carpi ulnaris, Ecr= extensor carpi radialis and Edc= extensor digitorum cummunis

O15.4 sEMG-based Speech Recognition for People with Laryngectomy

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BACKGROUND AND AIM: Each year thousands of individuals require surgical removal of their larynx due to trauma or disease, impairing their ability to speak. Studies of alternative forms of communication have found that synergistic activation of speech muscles - which largely remain intact after laryngectomy - produce unique combinations of surface electromyographic (sEMG) signals when articulating different phonemes. This is true even when speech is mouthed in a silent (unvoiced) manner, indicating that the use of sEMG signals for speech recognition could be a powerful platform to help individuals communicate after laryngectomy. Therefore, our group is working to develop a system that can translate patterns of sEMG signals recorded from muscles of the face and neck during silently mouthed speech directly into words for patients with laryngectomy.

Methods: We conducted experiments with n=7 participants with laryngectomy (mean age = 64, range = 57-75 years). Custom-designed miniaturized sEMG sensors were strategically placed on 8 muscles of the face and neck previously identified as those most involved in the articulation of speech. A vocabulary of 2,500 commonly used English words primarily from the TIMIT data corpus were presented in 980 phrases on a computer screen for subjects to silently recite by mouthing the words. A two-stage speech recognition algorithm was designed to process the sEMG signals recorded during silent speech. The front-end of the algorithm identified signal segments containing speech data and processed the speech-related segments with speaker-dependent window lengths and frame rates to compute Mel-frequency Cepstral Coefficients (MFCC). The back-end of the algorithm used subject-specific, multi-stage, Hidden-Markov Models to recognize the phonemes within each of the speech-related sEMG signal segments. The models were trained on 550 sentences and tested on a unique set of 430 sentences.

Results: We found that the synergistic activation of articulatory muscles during silently mouthed speech produced combinations of sEMG signals that could be used to discriminate different words and phrases with an average word error rate of 10.3 +/- 1.4%. Recognition was further improved in two participants who produced a larger training set for the recognition models. When reducing the number of sensors to 4, the average word-error rates moderately increased to 13.6%, indicating the viability of the system for practical use outside of laboratory settings.

Conclusions: These results provide first-time demonstration that unique combinations of sEMG signals obtained from synergistic speech muscles can be used for recognition of silently mouthed speech in patients with laryngectomy. While there is room to improve the accuracy, the ability to recognize words using phoneme-based patterns of sEMG provides an impactful first-step towards developing a practical facially-worn system for alternative communication for persons with laryngectomy.

O16 GAIT & POSTURE II

O16.1 Postural performance after bilateral or unilateral total hip arthroplasty

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Background and aim. Total hip arthroplasty (THA) is a successful treatment for several hip pathologies, able to relieve pain, to improve functional performance and quality of life, and to ensure an early return to activities of daily living. A considerable number of patients undergoing THA, requires a bilateral treatment. The advancements in surgical techniques have made the development of bilateral THA surgery possible through a one-stage procedure. This approach seems to be comparable to unilateral THA in term of postoperative complication rate and implies similar length of hospital stay, decreased operative time and overall cost reduction. However, no studies compare motor recovery in patients after bilateral or unilateral THA. The aim of the study is to compare the postural performance in patients operated of unilateral or simultaneous bilateral THA.

Methods.Twenty patients aged from 45 to 65 years old admitted for simultaneous bilateral THA (n=10) or unilateral THA (n=10) were enrolled in the study.They were assessed for symmetry in their lower limbs weight distribution (Body Weight Distribution Symmetry Index - BWDSI) and for postural stability (Global Centre of Pressure Length of Trace - LoT ; Centre of Pressure Length of Trace of the affected limb - LoTal) during a 45 seconds stabilometric task performed with open (OE) and closed eyes (CE). Walking ability was also evaluated through Timed Up and Go Test (TUG). Symmetry in body weight distribution and postural stability were assessed before surgery (T0), after three (T1) and seven (T2) days, while walking ability were evaluated only before and seven days after surgery.

Results. No significant differences in measurements between the two group were recorded at T0, except for LoT-CE which was greater in bilateral-THA group. Mixed Model ANOVA revealed significant between-group difference in body weight distribution during OE condition (BWDSI-OE) in favor of bilateral-THA group. A shorter length of CoP trace was observed in the unilateral-THA group in OE and CE conditions (LoT-OE ; LoT-CE). On the contrary, no significant difference was observed for length of CoP trace of the affected limbs in OE and CE conditions (LoTal-OE ; LoTal-CE). TUG showed no significant differences between the two groups (Table 1).

Conclusions. In the early postoperative phase patients undergoing bilateral THA showed better body weight distribution and similar postural stability of the affected limbs and walking ability, compared to patients undergoing unilateral THA.

Table 1

	Bilateral THA			Unilateral THA			P Value
	T0	T1	T2	T0	T1	T2	
BWDSI OE	14±8.1	8.5±6.3	7±5.5	11.5±9.9	19.9±12.2	15.7±9.3	0.024
BWDSI CE	10.7±6.9	10.1±5	9.1±6.3	11.38±11.5	19.2±10.9	12.8±11.2	0.119
LoTOE	427±130.6	529.5±116.6	581.6±152.5	368.4±81.3	410.4±142	395±125.7	0.029
LoTCE	674.3±298.3	801±229.4	704.4±250.4	425.7±82.9	470.2±165.4	503.6±205.9	0.004
LoTal OE	891.1±230.8	952.1±231.9	1005±215.8	851.7±274.4	964.5±295.9	913.4±301.6	0.667
LoTalCE	1088.5±394.5	1205.6±336	1155.1±319.8	905.4±219.8	965.4±268.4	1003±324	0.103
TUG	10.5±1.4	-	14.8±6.2	9.5±2.1	-	13.4±2.4	0.901

THA: Total Hip Arthroplasty ; **BWDSI**: Body Weight Distribution Simmetry Index ; **LoT**: Length of Trace ; **LoT-al**: Lenght of Trace affected limb ; **OE**: Open Eyes ; **CE**: Closed Eyes ; **TUG**: Timed Up and Go test

P Value refers to the comparison between bilateral versus unilateral THA

O16.2 Kinematic gait variability of individuals with a transfemoral amputation.

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BACKGROUND AND AIM; Instrumented gait analysis is an important tool in both the clinical care of individuals with a transfemoral amputation as well as in scientific research. In daily clinical care, gait analysis is used for selecting and setting a prosthesis according to the individuals' needs. In scientific research, it has helped us to increase the understanding of the gait pattern and allowed us to compare the effects of prosthetic components on group level. In almost all instances where instrumented gait analysis is used, there is a single measurement including a limited number of steps (5-15 steps). It is assumed that this limited amount of data is representative of the gait pattern. Whether this is true, however, is largely unknown Testing this assumption would require multiple measurements of on individual over time in which a high number of steps is included in the measurement. The goal of this study was to investigate the within-session and between-session kinematic gait variability of individuals with a transfemoral amputation.

Methods; Three individuals with a transfemoral amputation participated in this pilot study. They were measured during six session that were administered within 2 weeks and during different parts of the day (morning, early afternoon, late afternoon). We used a 6-camera opto-electronic motion capture system (Vicon) and placed reflective markers according to the Vicon plug-in-gait model. Markers were placed by the same person during all sessions. Data were processed using the Vicon Nexus software and analyzed in Matlab. Outcome measures included spatiotemporal variables and peak hip flexion and extension during the stride and peak knee flexion during swing.

Results; Of the studied data, the variability in peak prosthetic knee flexion during swing and walking speed were most prominent. Differences between sessions were quite substantial especially when analyzing less than 50 steps. Maximal differences in walking speed was 0.1 m/s between sessions (0.85 vs 0.95 m/s) when less than 50 steps were analyzed. This difference dropped to 0.03 m/s when at least 50 steps were included. The maximal difference in peak prosthetic knee flexion was 7 degrees between session (56 vs 63 degrees). This difference dropped to 4 degrees when at least 50 steps were included. When looking at the variability within a session, walking velocity dropped up to 0.12 m/s during a measurement session, even though substantial periods of rest were offered.

Conclusions; The results of this pilot study showed that the gait pattern varies between and within measurement sessions. These preliminary results show some indications that we might need to include more steps than is customary in amputee gait research. In addition, we might need to include gait variability next to measurement error when interpreting differences between prosthetic components. Future research including a bigger study sample should show whether our results can be replicated.

O16.3 Trunk and neck movements are reduced in people with chronic neck pain walking along a curved trajectory

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BACKGROUND AND AIM: Most often humans are faced with changes in path direction during everyday life (Segal et al. 2008) and few studies focus on walking along curved trajectories. Given the importance of neck sensorimotor control during walking and turning (Imai et al 2001) it is clinically relevant to consider the impact of neck pain which can pose neuromuscular and biomechanical disturbances and limit the ability to walk along rectilinear as well as curvilinear trajectories. People with chronic neck pain show changes in neuromuscular functions such as impaired posture control (Michaelson et al 2003) as well as a series of biomechanical constraints like a reduced range of neck motion and increased motion variability. The purpose of this study was to examine the ability of people with chronic neck pain to control trunk and neck motion walking along rectilinear and curvilinear trajectories.

Methods: Ten healthy subjects (control) and ten people with chronic neck pain (CNP, average ± standard deviation of pain = 4.6 ± 1.8 on a 0-10 numeric rating scale) agreed to participate in this study. 3D motion of trunk and head was acquired during walking along rectilinear (5 m) and curvilinear trajectory with 1 m radius (clockwise CW and counterclockwise CCW direction). Three acquisition trials were executed for each condition. Surface electromyography (EMG) was performed at the lumbar erector spinae (ES), sternocleidomastoid (Ste), and splenius (Sple) on the right and left side. The EMG activity was normalised as a percentage of the activity registered during one 10 s upright stance trial. Pitch, yaw and roll angles of trunk and head, and Root Mean Square (RMS) of EMG activity were extracted and averaged across the right leg walking cycles. Co-contraction index (CCI, Mohr et al 2018) was calculated for each pair of muscles (right and left side) and averaged across the right leg walking cycles. The extracted variables were averaged across repetitions and statistically evaluated using one-way ANOVA between the two participants' groups ($p<0.05$).

Results: Mean roll and pitch range of motion (RoM) of the head were significantly reduced in CNP during rectilinear and curvilinear walking compared to the control group ($p<0.04$). While, only during curvilinear walking, the roll RoM of the trunk in CNP was reduced compared to the control group ($p<0.016$). RMS of right Ste and left Sple as well as Sple CCI were significantly higher in CNP just during curvilinear walking ($p<0.04$).

Conclusions: CNP subjects show reduced head and trunk roll RoM only performing gait along the curvilinear trajectory. The restrained neck and trunk motion on the frontal plane can arise from the higher muscular activity at the neck level and higher co-contraction of the left and right splenius muscle across the gait cycle. Turning is accomplished by trunk inclination to the inner part of the trajectory to counteract the centrifugal acceleration on the body and this study is the first showing that pain at the neck level has a detrimental effect in controlling trunk movements on the frontal plane.

O16.4 Electromyographic analysis of the up and down step: comparative dry and water

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Background and Aim: Up and down a step is one of the most common daily tasks related to locomotion and a higher requirement for the lower limb. Electromyography is used daily for the assessment of muscle activity of different tasks. However one of the most common gestures that is performed in daily life like up and down steps has not been studied in the aquatic environment. The aim of the present study was to compare the muscular activity with surface electromyography of the lower limb and the trunk muscles during up and down step in dry land and into the water environments comparing young and elderly population.

Methods: An analytical cross-sectional inferential study was carried out in order to compare the muscle activation between dry land and aquatic environments. Sixteen non-pathological subjects participated in the present study. Eight muscles were recorded in a telematic and simultaneous manner by immersing the device in water (if necessary) with a sampling frequency of 1000 Hz. The functional task up and down step was performed at a rhythm of 5 repetitions at 25 BPM (measured using a metronome), the height of the step was 18 cm. The task was performed both in dry and in water with the same height of the step and the same rhythm in both environments. The waterline was in one meter, water temperature was 30°C.

Results: In older people, significant differences between dry and water during up step in the distribution of muscle activation were found. Young groups shown significant differences in all muscles analyzed with the exception of the spinal erector. However, for the down step in the group of young people (table 3), significant differences were observerd for all muscles except for the musculature of the trunk and rectus femoris In the aquatic environment, elderly group showed significant differences for the muscle activation compared to the young for all muscles of the thigh and leg except for the tibialis anterior during up step task. However, in the down step in the aquatic environment, only significant differences were obtained in favor of the elderly group in the musculature of the thigh.

Conclusion: Both, step up and down require more muscle activity in dry enviroment than in water for both elderly and young people. Likewise, older people require a higher level of muscle activation to step up and down than young people.

O17 EMG MODELING & PROCESSING II - SIGNAL ANALYSIS

O17.1 A Signal Quality Index for Electrode Location using Single-channel surface EMG features

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BACKGROUND AND AIM: The importance of proper electrode placement during surface electromyography (SEMG) has been addressed by many studies. Specifically, the importance of placing electrodes carefully to avoid innervation zones (IZ) and tendon regions has been emphasized. Placing electrodes in these regions can cause poor signal quality for two major reasons. First, signals containing incomplete and non-propagating action potentials will be collected. Second, action potentials passing under electrodes placed in a bipolar configuration within the IZ will be detected with opposite phases, causing cancellation and distorted action potentials to be collected. Placing electrodes over tendons or IZs can significantly alter the estimated feature values of SEMG signal. The multi-channel linear array can be used to identify IZ and tendon regions by comparing the phase and amplitude of waveforms across channels and performing cross-correlation between channels. However, compared to the single-channel technique, the linear electrode array requires more instrumentation, so it is less convenient and its use for judicious electrode placement is not widespread. The aim of this work was to distinguish between affected and unaffected channels with a feature value threshold that is consistent among subjects, so that it could be used as a signal quality index (SQI) that identifies acceptable electrode locations based on single-channel SEMG.

Methods: SEMG data were collected with a linear electrode array from the bicep brachii of 10 subjects during maximum voluntary contractions (MVC) and had quality of electrode location evaluated. Since placing electrodes in close proximity to the innervation zone or tendon regions is known to alter the waveform and affect characteristics features, a few features were extracted from each channel and tested to determine if one or more have a definitive separation in value between channels which should be rejected based on location and those that are acceptable.

Results: Test results on the bicep brachii of 10 subjects demonstrated promising performance in avoiding IZs with reasonable separation using Mean Frequency, Band Power Ratio, Average Motor Unit Potential and Mainlobe Width of Auto-correlation Function. Band Power Ratio hailed as the best index, able to detect 92.3% of the IZ-affected channels and 66.7% for tendon-affected channels, with a false alarm rate of 24.4% for unaffected channels. All indices have illustrated better performance on IZ-affected channels than tendon-affected channels.

Conclusions: The indices have performed well in avoiding channels affected by IZ. Knowing that tendon-affected locations can be avoided geographically, the indices show promise in becoming SQIs for acceptable electrode locations.

O17.2 Multi-channel analysis of the electrohysterogram by Entropy-based features to predict preterm birth and detect labor

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Background and aim: Birth occurring before completing the 37th week of gestation (preterm) remains a major reason of concern in obstetrics due to the high risk of long-term morbidity affecting preterm-born infants. Timely intervention is crucial to prolong gestation and improve neonatal outcomes. However, current diagnostics does not allow for early prediction of preterm birth. Analysis of the noninvasive uterine electromyogram, referred to as electrohysterogram (EHG), has been previously proposed as a potential indicator for (preterm) birth prediction. However, results on preterm subjects are inconclusive. In this study, we focus on the analysis of a large database of multichannel EHG signals recorded preterm.

Methods: Four-channel monopolar EHG signals were collected from 57 pregnant women admitted to the hospital with preterm uterine contractions. Signals were annotated by a team of experts in order to exclude from the analysis periods of uterine quiescence. Four different entropy-based features are here proposed and compared in their ability to predict preterm birth and to detect labor, irrespectively whether occurring preterm or at term. The synchronization of the time series obtained from the four EHG channels are analyzed both from couples of channels, by standard methods based on cross-Approximate Entropy (cross-ApEn) and cross-Sample Entropy (cross-SampEn), as well as by two novel approaches, referred to as multichannel- Approximate Entropy (multi-ApEn) and multichannel-Sample Entropy (multi-SampEn). These two new measures allow for a combined analysis of more than two channels. The classification performance of these Entropy features are assessed by comparing to the performance of the nonlinear Correlation Coefficient, a feature previously proposed in the literature for birth prediction from multichannel EHG analysis. To this end, the Wilkoxon sum rank test for separation between two classes is used.

Results: Multi-ApEn achieved the best prediction for preterm birth with enhanced significance ($p<0.03$) relative to the other features. For detection of labor, only multi-SampEn showed a significant difference ($p<0.05$) between the labor and non-labor group. This feature produced also the largest area under the receiver operating characteristic curve, AUC (AUC= 0.71).

Conclusions: Relative to the baseline methods for multichannel EHG analysis, Multi-ApEn and multi-SampEn show improved performance in predicting preterm birth and detecting labor, respectively.

O17.3 Long-Term Reliability Of Motor Unit Discharge Rates In The Flexor Carpi Radialis Obtained By Decomposition Of The Surface Electromyographic Signal

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BACKGROUND AND AIM: Decomposition of the surface electromyographic (sEMG) signal is a major advancement for non-invasive investigation of the neuromuscular system. This study evaluated the long-term reliability of motor unit discharge rates (MUDRs) in the flexor carpi radialis during isometric contractions of the wrist flexors at 60% maximum voluntary contraction (MVC).

Methods: There were four test sessions: one week between sessions 1 and 2; six weeks between sessions 2, 3, and 4. Participants (N = 20) performed 3 maximal isometric contractions of the wrist flexors and 3 ramp isometric contractions to 60% MVC. A load cell (load cell, MB-100 and SSMH, Interface Inc., Scottsdale, AZ) and 5-pin electrode (dEMG System, Delsys, Inc., Boston, MA) were used to monitor force and sEMG, respectively. The MUDRs were obtained using the Precision Decomposition Algorithm III in the dEMG Analysis software (Version 1.1, Delsys, Inc., Boston, MA), and calculated as the inverse of the smoothed (0.95 second Hanning window) firing intervals. The mean discharge rate was calculated during a one-second window centered at the plateau portion of the 60% MVC ramp contraction.

Results: Across the four test sessions, wrist flexion MVC was 92.00 ± 50.10 N (Mean ± Standard deviation). Repeated testing resulted in a 10% increase in strength ($p < 0.05$). The slight lack of stability was compensated for by a high degree of consistency, as evidenced by an intraclass correlation coefficient of R = 0.98. The MUDR was on average 15.69 ± 2.21 pps. There were no significant trends across sessions, and the greatest fluctuation was only 13% ($p > 0.05$). The consistency of scores within subjects was still very good (R = 0.79).

Conclusions: While the consistency of MUDRs was lower than force, the long-term reliability of MUDRs obtained by decomposition of the sEMG signal was still very good.

O17.4 Amplitude cancellation impairs the ability of the rectified EMG to reflect the neural drive to muscles

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BACKGROUND AND AIM: Surface EMG signals are often used to infer neural connectivity. The bi-phasic characteristic of bipolar motor unit action potentials, however, implies that some EMG amplitude is lost when action potentials from two or more motor units overlap. This phenomenon is known as amplitude cancellation. Recently, it was shown that amplitude cancellation not only reduces the EMG amplitude, but also distorts the power spectrum of the rectified EMG and thereby limits the ability of this signal to reflect the neural drive to the muscle.

Methods: In this study, we investigated the impact of this distortion using a computational model of the motor neuron pool, force, and EMG. The common synaptic input to the motor neuron pool was modeled as the sum of 30 sine waves (1-30 Hz) with random amplitudes. For each simulation setting, this procedure was repeated 15 times. To evaluate the degree to which the EMG reflected the neural drive, the linear relation between the 15 values of power of the rectified EMG and the cumulative spike train (CST; neural drive to muscle) was identified for each imposed frequency. In addition, an ideal EMG signal unaffected by amplitude cancellation (EMG_nc) was simulated by rectifying the motor unit action potentials prior to summation in the interference EMG. The linear relation between CST and EMG_nc was analyzed in a similar way as for the rectified EMG. Different sets of simulations varied the amplitude of the common input (evoking force standard deviations between 0.4 and 2.1 % of maximum voluntary contraction level; MVC) and contraction level (range: 1-15 %MVC).

Results: Across all simulations, the correlation between CST and rectified EMG was high at low contraction levels ($r^2>0.7$ at contraction levels <5 %MVC), but decreased when contraction level (and thus amplitude cancellation) increased. The magnitude of this decline was lowest with strong common input. For example, at ~10% MVC, R^2 was 0.2 with a common input evoking a force standard deviation of 0.4 %MVC, but 0.6 with a force standard deviation of 2.1 %MVC. Conversely, the correlation between CST and EMG_nc was always high ($R^2>0.7$). Remarkably, the decline in R^2 for the CST-EMG relation with increasing contraction levels was always greater for lower with respect to higher frequencies of common input. On average, at ~10 %MVC, R^2 for 1-5 Hz was 0.35 while for 16-30 Hz it was 0.61. Compiling all simulations, the average R^2 for CST-EMG was strongly negatively related to the magnitude of amplitude cancellation (r=-0.91).

Conclusions: These results show that amplitude cancellation impairs the degree to which the rectified EMG reflects the neural drive to the muscle. Specifically, EMG reflects the neural drive to the muscle only if the contraction level is low or if the magnitude of the common motor neuron input is high. Under other conditions, the distortion due to amplitude cancellation implies a weak correlation between the neural drive and the EMG.

O18 FATIGUE I

O18.1 Is the control scheme of motor unit behavior altered during muscle fatigue?

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Delsys and Altec Inc

BACKGROUND AND AIM: During fatigue, the Central Nervous System (CNS) increases excitation to the motoneuron pool to compensate for decreasing muscle force generating capacity [1]. Some studies indicate that increasing excitation leads to increasing motor unit firing rates [1], in agreement with the established control scheme that motor units modulate their behavior collectively in response to a common excitation, or Common Drive [2]. Other studies claim that, although the excitation increases, some motor units are selectively inhibited to decrease their firing rates [3]. Such divergent behavior would suggest that the common drive control scheme is altered during fatigue.

Methods: In this study, we investigated whether the control of motor units changes with fatigue by analyzing motor unit firing behavior in the first dorsal interosseous (FDI) of 5 healthy subjects (4 males, 1 female, 22-34 yo.) during isometric contractions sustained at 50% maximal voluntary force and repeated to exhaustion. Surface electromyographic (sEMG) signals from the FDI were decomposed to obtain the firing rates of active motor units [4]. sEMG signals from the flexor carpi radialis, extensor carpi radialis, and pronator teres were recorded to monitor the activation of surrounding muscles.

Results: Motor unit firing rates overall increased at the end of the protocol, but the increase was not consistent throughout the fatigue series. Firing rates increased progressively throughout most of the contraction series, and subsequently decreased to exhaustion in 4 of 5 subjects. Increases (decreases) in FDI firing rates were always associated with similar increases (decreases) in FDI activation. In contrast, decreases in FDI firing rates were always associated with significant increases in the activation of surrounding muscles.

Conclusions: Our findings indicate that the CNS may alter movement strategy by decreasing activation to the fatiguing muscle and increasing co-activation of surrounding muscles. Importantly, the direct relationship between changes in motor unit firing rates and FDI activation indicates that motor unit firing behavior follows natural changes in the excitation, and that the control scheme remains invariant with fatigue.

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O18.2 Neck muscle fatigue affects somatosensory evoked potentials and impacts motor skill acquisition and retention of a hand tracking task

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BACKGROUND AND AIM: Short latency somatosensory evoked potentials (SEPs) (8-30 ms) can be used to measure upper limb somatosensory processing in response to motor acquisition tasks. Following tracing a sinusoidal waveform with the thumb, changes are seen in SEP peak amplitudes related to cerebellar pathways, suggesting the cerebellum has a dynamic function in sensorimotor integration (SMI) [1]. Subclinical neck pain participants show differential changes in the amplitude of SEP peaks related to somatosensory pathways [2]. Altered afferent input from the neck due to fatigue and neck pain alters upper limb proprioception [3, 4] and is likely to alter the body schema, with the potential to impact upper limb performance accuracy. SEP peak changes are one way to measure the impact of altered neck sensory inputs on upper limb SMI. This study aimed to determine the differential effects of cervical extensor muscle (CEM) fatigue on motor training acquisition, and retention; and on sensory processing from distal upper-limb muscles, measured via median nerve SEPs.

Methods: 12 healthy individuals with no neurological conditions were randomly assigned to either a CEM fatigue or control group (6 per group). An isometric endurance neck muscle fatigue protocol was completed, monitored via electromyography (EMG). Both groups lay prone on a padded table but the fatigue group held a 2 kg weight with their head up against gravity, while the control group rested for 5 minutes. SEPs were recorded, in response to median nerve stimulation at wrist (1500 sweeps), at baseline and post motor training. Both groups completed a novel motor task with their right thumb, consisting of tracing a sinusoidal waveform varying in amplitude and frequency with different levels of complexity. Task retention was measuring 24-48 hours later.

Results: The CEMs fatigued after 6.16 (±1.98) minutes, with the mean power frequency significantly decreasing ($p=.0001$), and root mean square significantly increasing ($p=.0001$). There was significant effect of time for the motor task ($p<.001$). Both groups improved following motor learning acquisition ($P=.001$) and retention ($p=.001$), with less improvement for the fatigue group. After motor acquisition, the control group showed a significant increase in the N24 SEP peak amplitude ($P=.044$), while the fatigue group showed significantly increased amplitudes of the N24 ($P= .014$), N30 ($P=.022$) and P25 ($P=.027$) SEP peaks.

Conclusions: The decreased motor learning accuracy in the neck fatigue group suggests that neck fatigue may impair learning by affecting body schema. The differential changes in SEP peak amplitudes suggest that altered input from the neck affects neural processing of upper limb sensory inputs related to SMI. Neck muscle fatigue is an increasing problem due to increased use of technology with the neck held in a flexed posture. The fact that it can impact SMI and motor learning has important clinical and workplace implications.

O18.3 Exploring the physiological mechanisms of caffeine in a non-fatigued state and during fatiguing exercise - responders versus non-responders

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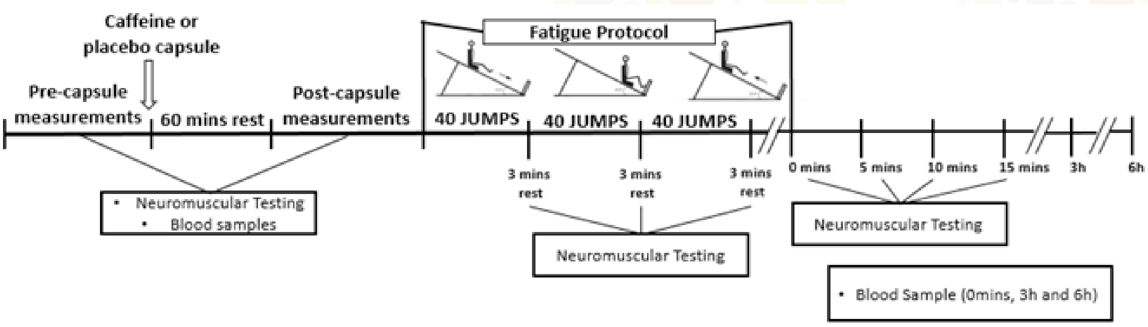
BACKGROUND AND AIM: Ergogenic effects of caffeine have been extensively reported, but its mechanisms of action are not yet fully understood. Furthermore, there is a large inter-individual variability of the responsiveness to this drug. Thus, there is an increased likelihood of encountering a masked effect of responders that cannot statistically be seen at the group level. The purpose of this study was to investigate the underlying mechanisms that may explain any caffeine-induced effects in a non-fatigued state and during exhaustive stretch-shortening cycle exercise (SSC).

Methods: Eighteen males participated in this randomised, double-blind, placebo-controlled crossover trial. The following baseline measures were made before administration of caffeine (6 mg?kg-1) or placebo: plantarflexion force, drop jump, squat jump, voluntary activation and contractile properties measured with the interpolated twitch technique, neuromuscular transmission (maximal Mwave), spinal excitability (H-reflex), corticospinal excitability and short-intracortical inhibition (SICI), intracortical facilitation (ICF) and corticospinal silent period (CSP) measured with transcranial magnetic stimulation and blood biomarkers. After a 1-hour rest, baseline measures were repeated, followed by a fatigue protocol that consisted of SSC exercise until task failure on a sledge apparatus by repeating series of 40 bilateral rebound jumps, with resting periods of 3 min. Neuromuscular testing was carried out throughout and after the fatigue protocol.

Results: Caffeine enhanced pre to postcapsule drop jump height without a significant ergogenic effect on isometric performance or concentric performance (squat jump). In a non-fatigued state, caffeine significantly decreased CSP, and suppressed a time-related decrease in ICF. Although, at the group level, caffeine administration did not increase the number of sets completed during a fatiguing task, 10 responders and 8 non-responders could be identified. Caffeine administration resulted in a mobilization of free fatty acids in a non-fatigued state, and during exercise. However, this increase was not significantly correlated with performance. An enhanced performance of responders may be explained by a caffeine-related decrease of SICI and CSP prior to the activity and a decreased sense of effort during the activity. Responders also benefited from an accelerated recovery of neuromuscular transmission failure after fatigue. This is partly corroborated by an observed significant main effect of drug on plasma levels of potassium that were attenuated in the caffeine condition.

Conclusion: Effects of caffeine are highly dependent on individual responsiveness and thus, examination of its effects on an individual basis is highly recommended. Caffeine seems to be ergogenic in fatiguing activity through its actions at different levels of the central nervous system.



O18.4 A motor unit-based model of muscle fatigue and recovery

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Understanding muscle fatigue and recovery is critical to the study of human performance in work, sport, and activities of daily living. We recently described a motor unit (MU) - based model of muscle fatigue that predicted, with good fidelity, endurance times for a variety of isometric contractions (Potvin & Fuglevand, 2017). That model used a previously published MU population model (Fuglevand, Winter & Patla, 1993) to simulate MU firing rates and forces to which we added time and intensity dependent changes in MU force, contraction time, and firing rate. The model could only be used to simulate sustained contractions. Yet in the real world, muscle fatigue does not usually occur in isolation and is influenced by previous bouts of muscle activity and the degree of intervening rest. The goal of this study was to advance the model to estimate muscle fatigue associated with a wide range of tasks that included varying periods of recovery from activity. We assumed that the recovery rates of force production by the muscle fibers of each MU were proportional to rates at which MU fibers fatigueds during activity. We also estimated recovery of MU firing rates following bouts of activity based on previously published data of the firing rates of mammalian motor neurons during sustained periods of intracellular current injection that were temporarily interrupted for varying durations (Sawczuk et al. 1995). (The model was then validated against 9 complex fatiguing tasks, with sustained forces at various increasing and decreasing levels (Sonne & Potvin, 2016). The model was able to accurately predict the progressive increases and decreases in muscle force that occurs during these tasks. The model shows promise for elucidating the relative contributions of different MU types to the fatigue and recovery associated with any type of isometric task and will have applications to the fields of ergonomics, rehabilitation, kinesiology and exercise.

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O18.5 Can Subjective Maximal Voluntary Contraction Be Measured Objectively?

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Background and Aim: Despite its routine use in research, no reference protocol for collecting maximal voluntary contraction (MVC) measurements exists in the literature, specifically, with regards to the number of MVC attempts to be performed and the duration of the rest period between contractions. The aim of this study was to develop a non-fatiguing MVC protocol for the biceps brachii muscle of healthy subjects.

Methods: A total of 41 subjects, ages 18-34, participated in the study. Subjects were randomly assigned to complete one of four MVC protocols with different rest periods (10, 15, 30, and 60 seconds) between each maximal contraction. Bipolar surface EMG electrodes recorded from the biceps brachii while subjects exerted their maximum force against a force sensor. Subjects performed a total of 25 MVC trials, with each maximal contraction lasting 5 seconds. For data analysis, the force produced during each MVC trial was taken as the peak-to-peak amplitude of the most maximal region on the force record. To normalize the force data, the greatest force produced by each participant was assigned as 100%, and the other force values were expressed as percentages of that maximum number. To evaluate the effect of fatigue, the normalized force data of each MVC trial was divided by the average normalized force data of previous trials. This resulting ratio was referred to as the force-fatigue index. A force-fatigue index of 1 was accepted to indicate that fatigue did not occur during that trial. Later, the force-fatigue indexes of each subject were summed to give the cumulative force-fatigue index. These data manipulations were similarly applied to the processed EMG data to produce the EMG-fatigue index and cumulative EMG-fatigue index for each subject.

Results: We found significant correlation of the observed data with the idealized cumulative force-fatigue index and the cumulative EMG-fatigue index, in the protocols with 10, 15, 30 and 60 seconds of rest. Overall, the means of the force-fatigue index varied between 0.92 and 1.03 and the means of the EMG-fatigue index varied between 0.94 and 1.05. MANOVA of the force-fatigue index revealed no effect of trial number on fatigue ($F(24, 14) = 1.691$, $p > 0.05$) and no trial number by protocol interaction ($F(72, 48) = 1.053$, $p > 0.05$). MANOVA of the EMG-fatigue index also revealed no effect of trial number ($F(24, 14) = 0.742$, $p > 0.05$) and no trial number by protocol interaction ($F(72, 48) = 2.074$, $p > 0.05$).

Conclusions: Our EMG and force data revealed no fatigue in any of the 25 MVC trials during the four protocols with different durations of rest. We conclude that a rest period as short as 10 seconds can be used between MVC attempts by the biceps brachii muscle of healthy subjects, without causing fatigue.

S9 SYMPOSIUM: AN INCREASED RELIANCE ON CONTRALESIONAL CORTICO-RETICULOSPINAL MOTOR PATHWAYS AND SENSORIMOTOR IMPAIRMENTS FOLLOWING A UNILATERAL BRAIN INJURY: GOOD OR BAD?

S9.1 The monoaminergic component of the reticulospinal system

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BACKGROUND AND AIM: The monoamines serotonin (5HT) and norepinephrine (NE) have potent effects on neurons throughout the CNS, but the strength of their effects on the spinal sensorimotor system is often underappreciated. The brainstem is the primary source of axons releasing 5HT or NE, which are part of the reticulospinal system. Increased reliance on the reticulospinal system following cerebral stroke would thus be expected to be accompanied by increased levels of 5HT and NE in the cord. To understand the predictions of this hypothesis, it is first necessary to define the normal effects of this descending monoaminergic system.

Methods: These following results are largely based in intra- and extracellular recordings in motoneurons in the cat preparation, supplemented with an overview of results from human subjects.

Results: Overall, both 5HT and NE act via presynaptic inhibition to reduce sensory input to motoneurons and via direct postsynaptic action to strongly facilitate the excitability of motoneurons. That is, they reduce sensory input and enhance motor output. This differential effect on synaptic input (decrease) versus motoneuron excitability (increase) is due to the presence of different receptor subtypes. 5HT1 and NE alpha 2 receptors mediate presynaptic inhibition in the dorsal horn while 5HT2 and NE alpha 1 receptors mediate enhance the excitability of motoneurons. These actions are not small. Extensor motoneurons for example have more synapses containing 5HT than synapse mediating the classic monosynaptic input from muscle spindle Ia receptors. Strong activation of the 5HT or NE receptors can increase the excitability of motoneurons by 300% or more, both amplifying and prolonging the effects of all descending and sensory inputs. Both of these actions are mediated by persistent inward currents (PICs). Presynaptic inhibitory effects are also very potent, acting to limit and focus sensory input with a particular focus on high threshold inputs such as those mediating the flexion reflex. It should also be emphasized that this system is extremely diffuse, with individual axons extending the length of the cord and branching at multiple levels.

Conclusions: Thus, the hyperexcitability of motoneurons seen post-stroke is entirely consistent with an increased monoaminergic drive to the cord. In particular, uncontrolled PICs are likely important for the difficulties in deactivating muscles that often occurs in stroke and for the excess excitability of many motor pools. These clear signs of excessive monoaminergic effect in stroke thus support the hypothesis that activation of the reticulospinal system is enhanced following stroke.

S9.2 The reticulospinal tract and recovery of hand function: second best is better than nothing

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BACKGROUND AND AIM: Control of the hand is typically assigned exclusively to the corticospinal tract, but our recent data from healthy monkey has revealed a role for the reticulospinal tract too. We have examined the distinctive role of this pathway in health and after recovery from lesion.
Methods: We used electrophysiological methods in macaque monkeys, whose motor system closely parallels that in humans.

Results: After recovery from corticospinal lesions, reticulospinal connections to motoneurons strengthen by around 2.5x (Zaaimi et al, 2012). There are also changes in the reticular formation itself during recovery, with some cell classes increasing firing rates by 1.6x. Together, these changes will raise reticulospinal drive to motoneurons by ~4x, providing a powerful substrate for recovery of activity. However, this has some limitations. Firstly, connections do not strengthen to extensors, for reasons which we do not yet understand. This may underlie the persistent residual extensor weakness which often bedevils stroke recovery. Secondly, reticulospinal output is less well fractionated than corticospinal; reticular outputs alone can produce only an approximation to the desired muscle activity patterns (Zaaimi et al, 2018). Reliance on this system will lead to awkward, inefficient movements with excessive co-contraction, as seen in severely impaired stroke survivors. As an overarching hypothesis, we suggest that recovery uses the best available remaining system. If substantial corticospinal resources remain, then these are strengthened and resculpted to restore movement. If there is too much damage to the corticospinal tract, then recovery must fall back to the 'second best' reticulospinal option: impoverished movement is better than none. Our recent data applying a non-invasive measure of reticulospinal efficacy to stroke survivors with a wide range of impairments supports this idea. Reticulospinal output was enhanced only in the individuals with the most severe disability.

Conclusions: This idea leads to the important consequence that physiotherapy must be stratified. After a severe stroke, the goal should be to enhance reticulospinal pathways as much as possible, whilst trying to minimise the impact of unwanted synergistic movements. Following a milder stroke, enhancing reticulospinal outputs is likely to be unhelpful, and the focus should instead be on surviving corticospinal fibres. This concept may help inform approaches to non-invasive stimulation and other attempts to manipulate CNS plasticity to boost recovery. Zaaimi et al (2012) Brain 135,2277.
Zaaimi et al (2018) J Neurophysiol 119,235.

S9.3 Rate Modulation and further evidence for changes in persistent inward currents during isometric dynamic torque tasks in chronic hemiparetic stroke.

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Stroke related loss of corticofugal pathways is posited to prompt increased reliance on remaining uninterrupted descending pathways; Motor unit activity during an isometric dynamic torque task suggests the intact reticulospinal pathway may play a major role. Previous studies have shown that individuals with chronic hemiparetic stroke exhibited reduced rate modulation in comparison to healthy controls at discrete torque levels. We further investigated motor unit activity as a function of torque during isometric torque ramps in multiple movement directions, and across individuals with different motor impairment levels. These dynamic tasks allow for the tracking of individual motor units through a continuous range of torques, both ramping up to 20% of MVT and back down, as well as across multiple torque ramps. We found the overall range of motor unit firing rates decreased for individuals with higher levels of motor impairment. Interestingly, we found that motor unit firing rates behaved differently during the ascending and descending portions of torque ramps, between impairment levels. Motor unit firing rate decreased at a slower rate in individuals with motor impairment than in healthy controls. This effect often coincided with tonic motor unit firing, spurred by the ascending portion of the torque ramp. In these subjects, motor units continuously fired during rest periods, though the firing rates did decrease from peak torque levels. This pattern of motor unit activity may be further evidence of increased persistent inward currents following a stroke, possibly mediated via an upregulated monoaminergic reticulospinal input. In further congruence with previous work, both the reduced motor unit firing rate and the increase in tonic firing between trials was observed more for distal muscles than proximal muscles, in individuals with greater motor impairments following stroke. Additionally, both phenomena are particularly prevalent in flexor muscles. The observed reduced firing rate, tonic activity, and flexor selectivity support the theory that an increased reliance on cortico-reticulospinal pathways may play a major role in motor impairments following chronic hemiparetic stroke.

S9.4 Evidence for an increased dependence on contralesional corticoreticulospinal pathways as a form of maladaptive plasticity post hemiparetic stroke

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Paretic arm and hand function is a major cause of chronic disability among stroke survivors. In addition to weakness or paralysis, the arm/hand is also affected by the abnormal flexion synergy - involuntary elbow, wrist, and finger flexion when an individual attempts to lift the paretic arm. The flexion synergy compromises the ability to reach and open the hand and reduces the control of grasp strength during functional tasks, thus compounding the stroke survivor's functional deficits. The fine motor control required for normal arm/hand function is largely driven by the contralateral corticospinal tract. Evidence will be provided, using high-density electroencephalographic recordings, that suggests that following a loss of corticospinal and corticobulbar (i.e., corticofugal) pathways post stroke, there is increased activation of contralesional motor cortices with increasing levels of paretic limb weight support by stroke participants, indicating the use of indirect corticobulbospinal pathways. Based on primate research, an increased reliance on these lower-resolution systems, especially the reticulospinal system, causes joint coupling patterns consistent with the flexion synergy pattern seen in humans post-stroke. Evidence will also be provided that in the most impaired stroke participants a greater reliance on contralesional motor cortices over time is resulting in an increase in structural tract integrity in contralesional reticulospinal tract integrity. Finally, evidence will be provided showing the reemergence of a developmental brainstem reflex, the asymmetrical tonic neck reflex, to show that anatomically diffuse reticulospinal motor pathways are active during flexion synergy expression. We interpret this progressive recruitment of contralesional cortico-reticulospinal pathways as an adaptive strategy that increases shoulder abduction strength at the cost of functional movement control in the paretic upper limb.

S10 SYMPOSIUM: NEUROMECHANICS OF JOINT STABILITY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

S10.1 Neuromuscular requirements for joint stability during sports with high risk of acute knee injuries

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The ability to maintain stability of the knee joint during external loading situations during sport and exercise is crucial for avoiding serious knee injuries. During injury risk situations such as side-cutting or landing from a jump, external joint moments may in some conditions impose substantial stress forces on the passive structures of the joint (i.e. ligaments and capsule). However, internal resistance produced by means of muscle activation opposes the external loading and can thus provide considerable dynamic joint stability. Sports specific biomechanical analyses have revealed that risk of injury to the anterior cruciate ligament (ACL) is higher when landing or cutting with more extended knee joint angles, in valgus positions and/or in conditions of internal or external knee joint rotation. Also, high external knee abduction joint moments during sports specific movements have been associated with increased risk of acute knee injury. The identification of such high-risk loading patterns implies that the hamstring muscles are important factors for the stability of the knee joint, which appears to be particularly true for the medial hamstrings. Indeed, prospective studies on neuromuscular coordination during injury-risk situations have shown that low medial hamstring activation is typical for healthy athletes later sustaining acute non-contact ACL- injury, while hamstring muscle strength per se is not a significant risk factor. Prevention of acute knee injuries, or rehabilitation after knee joint surgery before returning to sport, should therefore include exercises that focus on improving neuromuscular activation of the hamstrings, and in particular the medial hamstrings during sports specific risk movements. Studies that have examined prevention programs proven to reduce the risk of ACL injury in female athletes indicated that the main effect of these programs on neuromuscular activation is an increase the activity of the medial hamstrings during the initial ground contact phase of sports specific high-risk movements. Prevention and rehabilitation programs that contain a large variety of exercises are widely implemented. Although a general good effect of the programs on injury prevention is reported, only little information of the effect of the individual components of the programs exists. Therefore, current research is taking an increasing focus on the identification and development of specific exercises that are effective of improving neuromuscular activation during high-risk movement conditions.

S10.2 Tibiofemoral joint contact forces following ACL reconstruction and the association with cartilage and subchondral bone pathologies

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Background & Aim: Anterior cruciate ligament (ACL) rupture and reconstruction (ACLR) constitute a high risk for premature osteoarthritis (OA) of the tibiofemoral joint (TFJ), particularly if concomitant meniscal injury is present. This is of concern given the young age of most ACL-injured patients (i.e. 15-25 years). Inappropriate TFJ contact forces are considered a principal cause for increased OA risk. As muscle forces substantially contribute to TFJ loading, altered walking and sporting gait biomechanics following ACLR may substantially affect in vivo TFJ contact forces and, in turn, TFJ structure. Hence, the aim of this study was twofold: 1) to compare in vivo TFJ contact forces during walking, running and sidestepping gait tasks in ACLR patients (with and without concomitant meniscectomy) and matched controls, and 2) to explore relationships between walking TFJ contact forces and the structural health of the TFJ articular cartilages and subchondral bone in ACLR knees.

Methods: A computational EMG-driven neuromusculoskeletal model was used to estimate the muscle and tibiofemoral contact forces in participants with single-bundle combined semitendinosus and gracilis tendon autograft ACLR ($n = 104$, 29.7 ± 6.5 yr, 78.1 ± 14.4 kg) and healthy controls ($n = 60$, 27.5 ± 5.4 yr, 67.8 ± 14.0 kg) during walking (1.4 ± 0.2 m/s), running (4.5 ± 0.5 m/s) and sidestepping (3.7 ± 0.6 m/s). Magnetic resonance imaging was used to grade articular cartilage defects and bone marrow lesions (BMLs).

Results: ACLR participants had significantly ($p<0.05$) smaller maximum total and medial TFJ contact forces (~80% of control values, scaled to bodyweight) during the different gait tasks. TFJ contact forces were significantly related to the prevalence of cartilage defects and BMLs in the overall cohort of ACLR knees. Larger maximum medial TFJ contact forces significantly decreased the odds of large medial TFJ BMLs in ACLR knees (OR=0.90, Wald $\chi2(1)=4.93$, 95%CI=0.82-98, p=0.03). In healthy control knees, TFJ contact forces had no significant effect on the prevalence of defects or BMLs. In isolated ACLR knees, increased medial TFJ contact forces significantly decreased the odds of medial TFJ cartilage defects (OR=0.86, Wald $\chi2(1)=4.27$, 95%CI=0.74-99, p=0.04) and large medial TFJ BMLs (OR=0.83, Wald $\chi2(1)=6.55$, 95%CI=0.72-96, p=0.01). In contrast, in meniscal-injured ACLR knees, relationships between TFJ contact forces and both cartilage defects and BMLs were not significant.

Conclusions: TFJ under-loading occurs in post-ACLR knees and this was likely due to lower muscle forces and knee flexion moments and straighter knee during the different gait tasks. In knees with isolated ACLR, increased medial TFJ contact forces reduced the odds of prevalence of medial TFJ cartilage defects and large medial TFJ BMLs. However, if meniscal injury had been sustained, no statistical relationship between loading and pathologies was found. Findings will help inform post-ACLR physical rehabilitation programs and have important implications for long-term knee health.

S10.3 Longitudinal assessment of anticipatory and compensatory strategies following anterior cruciate reconstruction

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Among the most common injuries of the lower limb is the anterior cruciate ligament (ACL) tear, which leads to structural instability within the knee joint. Surgical reconstruction of the ligament can restore integrity of the knee joint, but neuromuscular control of the lower limb muscles may be undermined due to a reduced rate of voluntary activation that arises early after surgery as a result of arthrogenic muscle inhibition, compromising functional stability of the knee and increasing the risk of re-injury. Postural stabilisation of any body segment is achieved during voluntary movement by means of two neuromechanical strategies, namely anticipatory and compensatory strategies, aimed at minimizing predictable and unpredictable disturbances, respectively. Surgery related abnormalities in postural strategies have been investigated by previous authors during complex movements, such as jumping and running, which can be safely carried out during the late postoperative period only. In our previous study (Labanca et al. Eur J Appl Physiol, 2015), we designed a knee perturbation task involving predictable and unpredictable postural disturbances for the evaluation of anticipatory and compensatory responses, respectively, as early as two months from ACL reconstruction with patellar tendon. The task was derived from the loading-unloading bimanual paradigm (Massion J. Hum Neurobiol, 1984), i.e. the so-called barman test, which allowed to focus on the knee extensor muscles exclusively. The results showed that compensatory responses we delayed and that anticipatory responses initiated earlier in ACL compared to healthy participants. Recently, we have adopted a longitudinal approach to investigate changes in both anticipatory and compensatory strategies via the same perturbation task from the early, i.e. two months after surgery, to the late postoperative period, i.e. 6 months after surgery. The main finding was that, after six months from surgery, compensatory responses were still delayed in ACL compared to healthy participants, while anticipatory responses of ACL participants were not different from those of healthy participants. Overall, these results indicated that anticipatory strategies can adapt over time to the neuromechanical changes following ACL reconstruction, including a surgery related alteration of afferent signals from the knee and surrounding structures. This would suggest that the individual's functional level could significantly affect abnormalities in anticipatory strategies and that these abnormalities could be effectively reversed since the earliest postoperative phases by on time identification and intervention. Nonetheless, compensatory strategies should be targeted by stimulating the ability to quickly detect sudden changes in muscle length and to respond to unexpected joint perturbations, for a complete recovery of knee stability by the time of return to sport.

S10.4 Novel rehabilitation principles to target deficits after ACL reconstruction

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Most athletes who wish to continue sports after an anterior cruciate ligament (ACL) injury are advised to undergo ACL reconstruction (ACLR). Unfortunately, the overall athletes secondary ACL injury risk after ACLR is approximately 15%. For young athletes (25 years of age) returning to competitive sports involving jumping and cutting activities, secondary ACL injury rates of 23% have been reported, especially in the early return to sport (RTS) period. There is a plethora of data available that indicates that biomechanics are altered after ACLR that persist for several years and likely increase risk for injury to the contralateral side. Unfortunately, deficits in force generation and absorption during a vertical jump task are not related to time after surgery. If deficits are not effectively addressed in the early stages after ACLR, they may carry over to other, more complex motor skills later on. Given this outcome, it appears that current rehabilitation programs may not provide effective stimuli to patients after ACLR to improve their altered movement patterns. Components of current rehabilitation programs entail a combination of exercises to increase muscle strength, improve balance and endurance whilst reducing neuromuscular deficits. Although we acknowledge the importance to address these factors, there is a clear need for improvement in light of early development of OA and second ACL injury risk. An ACL injury should be considered as a neurophysiological lesion. Within this domain, possible explanations may be found to explain the cause of aberrant movement patterns. In an extensive review of the literature, we found no strong relationships found between proprioception and motor skills like balance and hopping. As such, the role of proprioception seems to be overrated. A more comprehensive analysis of neuroplastic changes after ACL injury is needed. Novel training methods may target asymmetrical movement patterns in patients following ACLR during activities that may pose athletes at risk for re-injury. Insight gained from recent motor learning research from our group may improve the effectiveness of secondary prevention of ACL injury and outcome in terms of returning to pre-injury athletic levels. In a systematic review, we established that using instructions

S10.5 A novel early exercise intervention following ACL reconstruction: neuromuscular electrical stimulation superimposed on movement

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Muscle strength deficit following anterior cruciate ligament reconstruction alters biomechanics of functional movements (Palmieri-Smith and Lepley, 2015). These deficits and alterations persist at the time of return to sport and for years after surgery. A number of interventions have therefore been designed to address this issue. Neuromuscular electrical stimulation (NMES) has been adopted to elicit externally generated muscle contractions either as single treatment or in combination with voluntary exercise. Additionally, eccentric exercise, biofeedback therapy or open and closed kinetic chain exercises have given interesting results. Despite these approaches have improved rehabilitation, deficits in strength are still reported. In order to create an effective training stimulus, it is important to start strength training as early as possible to reverse atrophy, and ensure an effective exercise intensity. This could be an issue in the early rehabilitation following ACL surgery as patients are not able to voluntary and fully recruit motor units. Further, it is not possible to overload the operated knee joint with high external loads. Our recent study (Labanca et al. 2018) was designed to investigate the effects on muscle strength and symmetry in lower limb loading of an early intervention based NMES of the quadriceps muscle superimposed while performing a functional movement, a sit-to-stand-to-sit, from the 15th to the 60th day following surgery, in addition to a traditional rehabilitation. The effects of superimposing NMES were compared to an intervention in which the same number of sit-to-stand-to-sit movements, without the superimposition of NMES, were performed, and to a traditional rehabilitation with no additional exercises.
Results have shown that superimposing NMES and functional exercises alone are both effective to recover symmetry in lower limbs loading while performing functional movements. However, superimposing NMES was the only intervention leading to a complete recovery of quadriceps muscle strength and less knee joint pain, both at the end of the intervention, 60th days after surgery, and in the longer term, 6 months following surgery. In conclusion, NMES superimposed to functional movements generates an effective exercise intensity just 15th days following surgery without overloading the operated knee joint. Thus, it is an effective training approach to recover quadriceps muscle strength early after ACL reconstruction. The superimposition on functional movements leads also to the recovery of symmetry in lower limb loading.

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O19 MUSCLE AND FORCE

O19.1 Why do muscles lose force potential when activated within their agonistic group?

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Background and Aim: A widely accepted assumption in biomechanics is that the force of a muscle is unaltered for given contractile conditions, independent if the muscle is activated alone or together with its agonists. However, recent experiments have shown that this may not be correct: quadriceps muscles lose approximately 20% of their maximum isometric torque generating potential when activated as a group1. One possible explanation for this loss in force may be the inability of muscles to deform freely when stimulated simultaneously because of increased inter-muscular pressure2. Thus, we hypothesized that lower inter-muscular pressures, resulting from lower activation levels, may reduce the loss in torque generating potential with simultaneous agonistic activation. Therefore, the aim of this study was to analyze the effect of activation level on the difference between quadriceps torques obtained by the sum of the individual muscle torques (isolated activation) and by the simultaneous activation of the target muscles.

Methods: Isometric torque measurements were performed for a range of activation levels on the rabbit quadriceps muscle (n = 3). Following dissection of the branches of the femoral nerve that innervate the vastus lateralis, vastus medialis and the rectus femoris, these muscles were activated in isolation and as a group using nerve stimulation frequencies ranging from 20 Hz (submaximal) to 100 Hz (almost maximal), thereby varying the force by a factor of approximately 5 fold. For each activation level the torques produced by the individual muscles when activated in isolation were added algebraically and the sum was compared to the torque produced by the simultaneous activation of the three muscles.

Results: The sum of the torque of the individual muscles exceeded the torque for simultaneous muscle activation by 10-50% across all levels of activation. When the data across all rabbits were pooled, a trend towards greater loss in torque for decreasing levels of activation was observed.

Conclusion: The force deficit observed when muscles of an agonistic group are stimulated simultaneously rather than in isolation persists across a large range of activation levels, forces, and inter-muscular pressures. We conclude from these results that inter-muscular pressure does not seem to explain the force deficit observed in simultaneous stimulation of agonistic muscles. Importantly, our findings imply that everyday movements performed at low levels of activation and force may be affected by the loss of force in simultaneous muscle stimulation.

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O19.2 Is explosive strength affected by fascicle tendon interactions?

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AIM: The ability of human skeletal muscle to achieve maximal force production in the shortest period of time is one of the key determinants of sport performance. Referred to as explosive strength, this capacity is classically evaluated through the maximal rate of force development (RFD). It is well established that RFD is strongly influenced by the neural system (Maffiuletti et al., 2016). However, little is known regarding the contribution of fibers' arrangement and fascicle-tendon interactions to RFD. The present study aimed to explore the influence of muscle-tendon interactions on explosive performance.

Methods: Sixteen participants performed six sets of five voluntary isometric contractions at -20, -10, 0, 10, 20 and 30° of plantarflexion (0°, neutral position) and five no load ballistic contractions (Hauraix et al., 2015). RFD was measured as the rise of torque between 0 and 100ms. Muscle-tendon behaviour was recorded on gastrocnemius medialis muscle using high-frame rate ultrasound. Force-length and force-velocity relationship were determined from voluntary contractions according respectively Hoffman et al. (2012) and Hill (1938) model.

Results: RFD showed a significant effect of the ankle angle ($P<0.001$) and were maximal at 0° (475±105Nm/s). During the RFD at 0°, fascicles operated on a range of force-length relation where force is not significantly affected. Thus, at this specific angle, force-length relationship did not affect RFD. In addition, peak shortening velocity was measured 92±4ms after the onset of torque at 36.5±9.4% of maximal fascicle velocity. Considering the force-velocity relationship, this high shortening velocity decreased the maximal force that fascicle can produce. Thus, we estimated that the force produced throughout fascicle shortening was maximal after 92±4ms until the maximal force (fig.).

Conclusions: The significant decrease in RFD at 10, 20 and 30° was in agreement with the decrease of torque according force-length relation. Interestingly, fascicle length decrease during the RFD could be divided in two phases. First, from 0 to 92±4ms, fascicle velocity reached a peak and the force increased progressively. This could be explained by the motor unit recruitment which is the key determinant of this first phase. Second, after peak, shortening velocity decreased gradually while the torque increased. Torque was maximal when shortening velocity was null. Therefore, the force is directly related to the force-velocity properties of fascicles and the present study demonstrates that RFD is strongly influenced by muscle tendon interactions.

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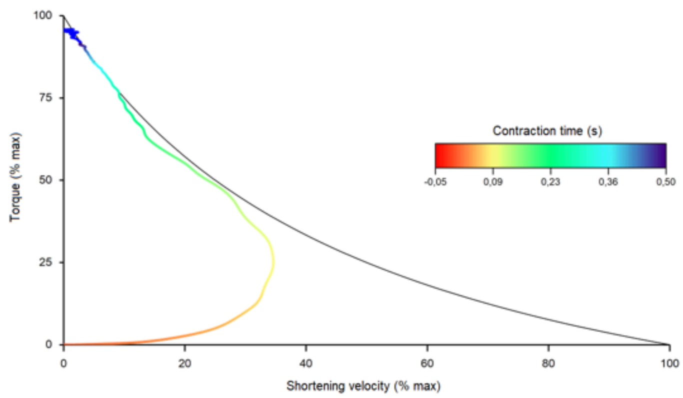
Figure: Mean subjects torque and fascicle shortening velocity was measured during RFD according to force-velocity relation. Torque-fascicle shortening velocity relation (black line) was expressed in % of maximal. During RFD, pattern of torque versus fascicle shortening velocity variation was expressed over contraction time (rainbow line). We estimated that the torque produced throughout fascicle shortening was maximal when the difference with the two lines was below 5%.



O19.3 Measuring In Vivo Muscle Architecture Parameters to Determine Changes in Optimal Fascicle Length and Physiological Cross Sectional Area Following Hemiparetic Stroke: Preliminary Findings

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BACKGROUND AND AIM: Despite important recent advances, there is no in vivo muscle imaging study that measures all of the critical architectural parameters for any upper limb muscle, in any population. Here we combined multiple novel imaging methods to measure each parameter needed to calculate optimal fascicle length (OFL) and physiological cross-sectional area (PCSA) in the biceps brachii. We compare inter-limb differences in a participant with hemiparetic stroke (M, 59 yrs, Fugl-Meyer 24) to an able-bodied, age-matched participant with no history of musculoskeletal disease or injuries of the upper limb (M, 61 yrs). Sarcomere length, fascicle length, and muscle volume of the biceps were measured in vivo in both arms under passive conditions. PCSA and OFL were calculated from these data using 2.7μm as optimal sarcomere length.

Methods: To image sarcomeres in vivo, a microendoscopic needle was inserted into the long head of the biceps with its optical lenses aligned parallel to the fascicle direction. A microscope (Zebra Medical Tech) which uses second-harmonic generation to capture the intrinsic striation pattern of sarcomeres was attached to the needle. Mean sarcomere length was calculated offline from an average of 15 images per arm[1]. Separately, extended field-of-view ultrasound images of the long head of the biceps were obtained[2]; 3 images were obtained per arm, 4 fascicles were measured per image. In both studies, participants were seated, secured to a chair, with their arms supported in a controlled posture. In a third study, the Dixon method, a fat suppression MRI sequence, was used to acquire biceps volume (3D GRE, TR=7ms, TE=2.39/4.7ms, flip=12°, matrix=256x216, slice=3mm); manual segmentation was performed using Analyze 12.0 (AnalyzeDirect). Volume of muscle contractile material was calculated as the volume of intramuscular fat subtracted from the total biceps volume[3].

Results: Inter-limb differences in volume (23.1%) and average fascicle length (18.5%) were markedly more pronounced in the participant with chronic hemiparetic stroke (Fig.1). For the able-bodied participant, absolute differences between limbs were <5% for all parameters. Biceps sarcomere lengths in the paretic limb of the stroke participant were ~6% longer than those in the non-paretic limb. Inter-limb differences in fascicle and sarcomere length resulted in an OFL that was 22.6% shorter in the paretic limb. The concomitant decrease in muscle volume resulted in remarkably comparable muscle PCSAs across limbs, the only architectural parameter that was not more different between limbs in the participant with hemiparetic stroke than the corresponding measure in the control participant.

Conclusions: This study demonstrates the feasibility of collecting comprehensive, in vivo muscle architecture data sets in individuals with severe motor impairments. 1.Sanchez et al.Neuron.88:2015. 2.Nelson et al.J Biomech.49(9):2016. 3.Garmirian et al.Proceedings of ASB,Boulder,CO,2017.

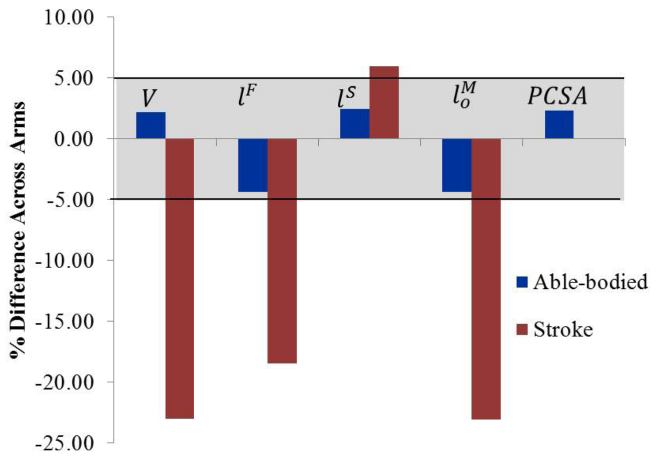

Fig. 1: Percent difference between limbs, normalized to nonparetic (or dominant) arm. Negative indicates the value from the paretic (or non-dominant) arm is smaller.

O19.4 Muscle belly gearing differs between gastrocnemius medialis and lateralis during submaximal isometric contractions

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BACKGROUND AND AIM: Belly gearing allows a muscle to shorten at a higher velocity than the shortening velocity of its muscle fibres and is expressed as the ratio of belly shortening velocity over fascicle shortening velocity. The gastrocnemii have predominately been considered as similar muscles with similar gearing ratios during contraction. However, the fibre arrangement of gastrocnemius medialis (GM) and lateralis (GL) differs considerably allowing the fibres of GL to shorten at higher velocities than the fibres of GM. This could result in differential belly gearing between the two muscles. The purpose of this study was to investigate whether muscle belly gearing differs between GM and GL during a submaximal isometric contraction.

Methods: The muscle bellies and muscle-tendon junctions (MTJ) of GM and GL of 18 participants (11 males, age 39.8 ± 9.3 years, height 173.9 ± 8.2, body mass 72.7 ± 11.0) were imaged during submaximal isometric contractions to 70% of each individual's maximum voluntary activation level using ultrasound. Fascicle lengths and pennation angles were determined in ultrasound images of the muscle belly using the tracking software UltraTrack. Belly shortening was determined as proximal displacement of the MTJ (direct method) by tracking the displacement of the MTJ using custom-written MatLab code. Belly shortening was also determined from proximal displacement of the fascicle attachment point on the deep aponeurosis (indirect method), providing two measures of belly gearing for each muscle head.

Results: Determined with the direct method, GM belly gearing was 1.7 ± 1.1 and GL belly gearing was 0.1 ± 2.1 and differed significantly between both muscles ($p < 0.001$). Gearing also differed significantly between GM and GL when calculated with the indirect method (1.1 ± 0.05 and 0.9 ± 0.5, respectively; $p < 0.05$). The calculation method had a significant effect on GL belly gearing ($p < 0.01$) but not GM belly gearing ($p > 0.05$).

Conclusions: This study showed that muscle belly gearing of GM and GL differs during isometric submaximal contractions. Gearing calculations were considerably affected by the method used to determine belly shortening, which must be considered when calculating belly gearing of a muscle. With both methods, GM belly gearing was > 1 indicating greater shortening velocity of the muscle belly than the muscle fibres. GL belly gearing was << 1 indicating much greater fascicle shortening velocity than belly shortening velocity. These findings support the view that GM and GL have different functions as plantarflexors even when the muscle-tendon unit acts isometrically.

O19.5 Does the shear wave propagation velocity behave in accordance with the uneven myoelectric activity of rectus femoris during hip flexion contractions?

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AIM: The uneven, task-dependent myoelectric activity has been previously demonstrated within the human rectus femoris (RF) muscle [1]. Beyond neural activation pattern of the muscle, knowledge about the passive elastic properties assessed by supersonic shear wave imaging (SSI) ultrasound elastography could help the understanding of muscle behaviour during contractions [2]. It has been already showed that surface EMGs and SSI measurements are well correlated [3]. Nevertheless, if the shear wave (SW) velocity measured by SSI has a localised response within RF muscle as observed in the EMGs amplitude remains an open issue. The purpose of this study is therefore to answer the question: does the SW velocity measured by SSI have an uneven response along RF muscle during hip flexion isometric contractions?
METHODS: Ten healthy male volunteers had their RF longitudinal length equally divided in three sites and the centre of each were defined as RF proximal, middle and distal regions. They were then asked to sat on a chair (knee and hip flexed at 90º) with the right leg fixed to a force transducer and perform four trapezoidal isometric contractions of hip flexion (once for the EMGs and three for SW velocity) at 40% and 80% MVC. Two pairs of electrodes centrally positioned to each RF region were used to acquire the electromyograms. The SW velocity was collected using AIXPLORER V9 (Supersonic Image, Aix-en-Provence, France), 15-4 MHz transducer positioned longitudinally to the RF regions. The average of SW velocity and the root mean square (RMS) of EMGs were centrally computed on an epoch of 3 seconds during the force plateau region. The data were then normalised considering the higher value reached during each task. The Wilcoxon Rank Sum test was used to compare the SW velocity and RMS values among RF proximal, middle and distal regions.

Results: A significant difference was observed among RF regions for both normalised SW velocity and RMS values at 80% MVC ($P<0{,}01$ for both cases). Specifically, for both measurements the proximal RF region presented higher values than the other regions. However, no differences were observed among regions for 40% MVC.

Conclusion: Our main findings suggest a localised response of SW velocity within RF muscle in higher contraction levels. The RMS results are in accordance with previous study [1], where the RF proximal region presented higher values in comparison with the other regions only for 80% MVC. Interestingly, the same behaviour could be observed for the SW velocity. Recent evidence observed that the SW velocity present distinct responses among quadriceps heads [4], and our results suggest that these variations are extendable to different sites within the same muscle. Researches might therefore consider the use of electromyography and supersonic shear wave imaging elastography measurements along distinct RF regions to better understand the components involved with the muscle force generation.

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O19.6 Identification of time-varying joint impedance using single trial data

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BACKGROUND AND AIM: Quantification of human joint impedance is important to enhance our understanding of how the central nervous system controls human posture and movement. During movements humans continuously regulate their joint impedance which ensures our versatility to interact with the environment. To quantify joint impedance during movement the use of time-varying (TV) system identification techniques is required. Traditionally, ensemble averaging of many recordings of the same task is required to obtain a good model of joint properties. However, joint impedance differs from trial-to-trial due to inherent human variability. Quantifying joint impedance based on data from a single trial allows to investigate trial-by-trial changes. The aim of this study was to demonstrate how a novel parametric and a non-parametric TV system identification method can be used to monitor TV joint impedance during a force task based on single trial data.

Methods: Experiments were performed in which participants exerted a TV torque by flexing the wrist (between 5-20% of their maximum voluntary torque) against the handle of a robotic wrist manipulator. Meanwhile, the manipulator applied small continuous angular multisine position perturbations to the wrist joint. The perturbation signal contained a sparse set of excited frequencies between 0.1-20 Hz and had an RMS amplitude of ~1.1 deg. Participants were instructed to track a target line representing the required torque (0.05 Hz sine wave) presented on a monitor, while ignoring the angular perturbation on the handle of the manipulator. Each trial lasted 50 s and was performed 6 times. Mechanical data (wrist angle and exerted torque) were used to estimate TV joint impedance using two novel linear time-varying (LTV) system identification methods: (1) kernel-based regression (KBR) (Lataire et al., 2017, IET Control Theory & Applications) and (2) non-parametric skirt decomposition (Lataire et al., 2012, Automatica). Identification was performed on single trials and the estimators included no prior assumptions regarding the underlying TV joint mechanics.

Results: Both methods revealed that the voluntary sinusoidal joint torque, by activation of the wrist flexor muscles, resulted in a sinusoidal TV joint impedance, mainly expressed by a variation of the resonance frequency. The parametric kernel-based estimator using a 3rd-order differential equation explained >78% of the variance of a single trial. The non-parametric skirt decomposition method explained >83% of the variance.

Conclusions: This study demonstrates TV joint impedance can be described using LTV identification methods on single trial data. The proposed system identification methods can be applied to obtain additional insights in the control of movement in health and disease and may be valuable in for example the design of (active) prostheses and orthoses.

ORAL PRESENTATIONS

Monday, 2nd July

Monday July 2nd

S11 SYMPOSIUM: NEUROMECHANICAL ADAPTATIONS AFTER TRAINING AND EXERCISE

S11.1 The motor unit plasticity under the influence of a strength training, endurance training and functional muscle overload

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The adaptation of contractile properties of motor units in rat medial gastrocnemius to the strength and the endurance training as well as the muscle functional overload was studied. The endurance training was performed on a standard laboratory treadmill (animals were running at 30 m/min up to 80 minutes daily). The strength training was performed with the custom-made resistance apparatus, in which rats were climbing to reach food against a load put on their shoulders (the resistance progressively increased up to more than 200% of body weight). Compensatory overload of the medial gastrocnemius was induced by tenotomy of its synergists (lateral gastrocnemius, soleus, plantaris). The endurance training modified proportion of motor units, predominantly increasing a proportion of fast fatigue-resistant units, increased their resistance to fatigue, shortened the contraction time and increased ability to potentiate the twitch force. The strength training had no influence on proportions of three types of motor units but increased the force of fast and slow units, shortened the twitch time parameters of slow and fast resistant motor units, modified the force-frequency relationship and increased the twitch force potentiation in fast fatigue-resistant units. This training decreased also the early fatigue effects (within first 15 seconds of repeated activity) in fast fatigable motor units. The muscle overload decreased a proportion of fast fatigue-resistant motor units, shortened their twitch, increased the force and ability to potentiate the twitch of fast units. Moreover, the overload considerably modified the force-frequency relationship of fast and slow motor units. The twitch-to-tetanus ratio was reduced for fast fatigue-resistant motor units in animals from the two trained groups and for all motor unit types in overloaded animals. In conclusion, the increased muscle activity evoked by training and muscle overload result in adaptive changes of motor unit contractile properties which are type-specific and most expressed in fast motor units.

S11.2 Training-Related Changes in Motor Coordination: Balance Exercises And Sports Medicine

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BACKGROUND AND AIM: Inter-muscular coordination is an essential part of sports performance, as smooth and precise movements substantially contribute to maximize efficiency. In terms of sports injuries, movement technique has been considered a risk factor in case of knee and ankle sprains, which are common injuries in team sports. In some cases, such injuries are caused by poor management of the center-of-mass position and/or lack of balance recovery strategies. Balance control has been improved through balance/neuromuscular training interventions, which can contribute to reduce injury incidence in sports. However, little has been shown regarding the direct influence of such interventions on postural control during motion patterns related to sports injuries. Therefore, the aim of this presentation is to describe the effects of balance training on neuromuscular control of common sports gestures such as side-step cutting and landing.

Methods: in two separate studies, 45 physically active college students were assigned to control and balance training groups. In one experiment, the task was related to side-step cutting, whereas in the other experiment the task was landing from a lateral jump. We used the concepts of muscle synergies or motor modules to express the relationship between multi-muscle electrical activities (electromyography - EMG) in such dynamic conditions. Motor modules were extracted from multi-muscle EMG signals using non-negative matrix factorization (NMF). Additionally, knee abduction moments were computed for the side-step cutting task, whereas ankle joint work was computed for the lateral landing task.

Results: Balance training altered inter-muscular coordination, leading to changes in specific modular activation patterns. For instance, motor modules related to trunk and hip extension were altered during the stance period of side-step cutting, increasing the activation of such muscle groups during early stance. These changes in muscle recruitment were related to significant reductions in peak knee abduction moments. Likewise, it was found an independent recruitment of the ankle joint muscles during landing following balance training, in which muscles related to medial-lateral ankle stability were recruited more independently from whose related to anterior-posterior joint function. This selective muscle recruitment induced significant reductions in the medial-lateral ankle joint work, which is highly relevant to reduce the medial-lateral loading usually present during ankle sprains.

Conclusion: Our results suggest that adaptations from balance training were related to enhanced overall motor control strategies towards reducing undesired kinetic patterns, which are usually present in injury events. Therefore, the use of NMF as a tool to understand motor coordination in sports is promising, and can substantially contribute to the understanding of neuromechanics in sports medicine.

S11.3 Changes in the behavior of longitudinally-tracked motor units following four weeks of isometric strength training

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BACKGROUND AND AIM: Several studies have shown that strength training results in an increase in the neural drive to muscle. However, the specific motor unit adaptations following training remain unknown. In this study we tracked the behavior of large populations of motor units following four weeks of isometric strength training by using surface EMG decomposition.

Methods: Twelve subjects performed four weeks of isometric ankle-dorsiflexion strength training. Training involved 30 ballistic contractions (rapid contractions) and 30 gradually increasing contractions up to 75% of maximal voluntary force (MVC) with a plateau of 3 s. The main trial measurements consisted of linearly increasing ramp contractions up to 70% MVC. The myoelectrical activity of the tibialis anterior muscle was recorded with a high-density surface EMG grid of 64 electrodes. The EMG signals were decomposed into individual motor unit action potentials. Moreover, the motor unit action potentials were tracked pre- and post-strength training and associated to voluntary force.

Results: The presented results are from a preliminary cohort of 5 subjects. The total number of tracked motor units was 238, with an average of 48 ± 18 per subject. The maximal voluntary strength increased significantly following training [pre: 308.4 ± 38 to post: 349.2 ± 33.7 (N), 13.9 ± 10.8 (%), $P<0.001$]. The training intervention did not change the absolute force value at which individual motor units were recruited ($P>0.05$), although the recruitment thresholds normalized with respect to MVC decreased (by 7.4 ± 3.9 %MVC on average, $P<0.001$). The motor unit discharge rate at recruitment and de-recruitment did not change ($P>0.05$). On the other hand, the average motor unit discharge rate during the plateau of the ramp contractions increased after training [17.5 ± 1.32 vs 19.7 ± 1 (pps), $P<0.001$].

Conclusions: Four weeks of isometric ankle-dorsiflexion strength training decreased the motor unit recruitment thresholds and increased the discharge rate of motor neurons innervating the tibialis anterior muscle. The present results can be interpreted as an increase in the synaptic input to the motor neuron pool following training.

S11.4 Differential changes in motor unit properties following either endurance or high-intensity interval training: New insights with high-density surface EMG decomposition techniques

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BACKGROUND AND AIM: Recent advances allow large populations of motor units (MU) to be tacked longitudinally which has lead to an improved understanding of neuromuscular adaptations induced by training. Here, we compared MU adaptations to two different training paradigms that reportedly induce similar changes in cardiopulmonary fitness and aerobic metabolism despite large differences in load intensity and volume. In these series of studies, we used MU decomposition techniques with the aim of understanding the neuromuscular adaptations underlying differences in motor function following both training regimes.

Methods: Sixteen men were assigned to endurance (END) or high-intensity interval training (HIIT) (n=8 each) and performed six training sessions over 14 days. Each session consisted of 8-12×60s intervals at 100% peak power output (PPO) separated by 75s of recovery (HIIT) or 90-120min continuous cycling at ~65% VO2peak (END). Pre and post intervention, participants performed maximal (MVC), submaximal (10, 30, 50 and 70% MVC) and sustained (until task failure at 30% MVC) isometric knee extension as HDEMG signals were recorded from the vastus medialis (VM) and vastus lateralis (VL) muscles. HDEMG signals were decomposed (submaximal contractions) into individual MU by convolutive blind source separation and MUs were tracked across sessions by semi-blind source separation. HDEMG average rectified value (ARV) amplitude, MU discharge rate and conduction velocity (MUCV) was assessed for the sustained 10, 30, 50 and 70% MVC contractions as well as during the endurance contractions until failure (30% MVC).

Results: The HIIT group showed enhanced maximal knee extension torque by ~7% ($p=0.02$) which was accompanied by an increase in ARV amplitude (?50% knee extension MVC) and discharge rate for high-threshold MU ($p<0.05$). In contrast, the END group increased their time to task failure by ~17%, but showed no change in MU discharge rates nor ARV amplitude ($p>0.05$). Both training interventions induced changes in MUCV, but these changes also depended on the type of training ($p<0.001$). HIIT showed higher values of MUCV following training at all torque levels ($p<0.05$), whereas the END group only displayed changes in MUCV at low torque levels (10-30% MVC, $p<0.002$).

Conclusion: Despite reported similarities in aerobic metabolism following HIIT and END interventions, our results suggest that differences in load intensity and volume induce diverse adjustments in MU behavior. The availability of new decomposition techniques which allow MU to be identified and tracked longtitinally (even during high levels of muscle activation) improved the reliability and sensitivity of detecting the neuromuscular changes occurring following these two training interventions.

S11.5 Adaptations in the common synaptic input to populations of motor neurons after motor learning

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BACKGROUND AND AIM: The learning of a complex force-matching task involving isometric contractions creates significant adaptations in the neural drive to muscles. Previous research has shown that after skill acquisition motor unit discharges decrease in variability, whereas the amplitudes of the modulation frequencies increase. These findings likely imply that the neural control of motor neurons may become more tuned to the frequency content of the desired force profile during the learning process. In this study, we investigated this problem using a complex force matching isometric task and high-density electromyographic (EMG) recordings in the tibialis anterior muscle.

Methods: Five subjects performed 15 repetitions of a complex isometric force-matching task of the tibialis anterior muscle in the same session. Informed consent was obtained from all participants. The force feedback was a stochastic signal with a duration of 30 s, a bandwidth of 0-1 Hz, mean value of 10 % MVC and a standard deviation of 1 % MVC. The same noise realization was used for all subjects. The subjects rested 60 s between consecutive trials. Cross-correlation between the exerted force and the provided feedback was calculated to estimate the improvement in the force-matching ability. High-Density EMG signals were recorded from two matrices of 64 electrodes. Convolutive blind source separation was applied to the first (1) and last (15) recording for the identification of motor unit spike trains. The power spectra of the composite spike trains were compared to their shuffled version to quantify the amount of shared synaptic input to the pool of motor neurons (common input ratio). Statistical analysis was performed on the transformed ratio values between the original power spectra and their shuffled version in the frequency ranges 0-5 (delta), 5-15 (alpha) and 15-30 Hz (beta).
Results are reported for five subjects.

Results: 83 and 78 motor units were identified in the first and last repetition respectively. The correlation between the generated force profile and the feedback was 0.65±0.11 in the first repetition and increased significantly to 0.82±0.05 in the last repetition. There was a significant increase in the peak of the common input ratio in the delta band (0.37±0.13 vs 0.60±0.09, p=0.028). Moreover, the significant coherence peaks in the alpha band decreased from the first to the last repetition, but no change was identified in the beta band.

Conclusions: These findings indicate that the shared synaptic input to populations of motor neurons is tuned to the desired force oscillations during the acquisition of a new skilled force-matching task. In the last repetition, shared oscillations in the frequency ranges different from the one of the feedback signal were absent or decreased compared to the first repetition. The results provide indications on the role of the shared synaptic input during isometric force-matching task.

S12 SYMPOSIUM: NEW INSIGHTS INTO TRUNK CONTROL IN BACK PAIN THROUGH NOVEL APPROACHES

S12.1 New ways to probe and measure spine movement quality and motor control.

Ryan Graham
University of Ottawa

BACKGROUND: Low back pain (LBP) is a major public health issue, affecting over 80% of people at some point in their lifetime with 85-90% of cases classified as non-specific (i.e. no recognizable pathology). Among serious chronic conditions, LBP is a leading cause of visits to a physician. The progression towards chronic LBP is known to be multifactorial, resulting from one or more pathoanatomical, physical, neurological, physiological, psychological and social factors. Combined these contribute to a biopsychosocial model of LBP progression. Consequently, an accurate diagnosis of LBP is very difficult to accomplish, which often leads to inadequate intervention management strategies, unnecessary specialist referrals, inappropriate medical imaging, and overall improper health care utilization [1]. While LBP is recognized as being multifactorial and often difficult to specifically diagnose, spine motor control is widely recognized as an important factor in the development, progression, and recurrence of LBP [2].

Methods AND RESULTS: In this symposium, I will introduce and discuss novel methods and techniques that my research group has been using to measure spine movement quality and control in the laboratory as well as in clinical and real-world settings. More specifically, I will introduce: a) the dynamical systems approach and methodologies that we use to assess spine motor control and movement quality (i.e. local divergence exponents, relative phase analyses, and new collaborative work that we have been pursuing to validate these outputs against systems identification methods [3]); b) new research aiming to combine a novel spine inter-vertebral (I-V) motion model [4] with pattern recognition (e.g. principal component analysis) and machine learning (e.g. support vector machine) techniques [5] to characterize spine I-V neuromuscular control strategies during dynamic spine movements; and c) a novel, real-world, smart-device assessment system that we have developed, which combines inertial measurement units with cloud computing and artificial intelligence, in order to both assess spine motor control and movement quality while simultaneously providing scoring criteria in real time [6].

Conclusion: I will conclude the talk by discussing how we are partnering with the Ottawa Hospital Research Institute as well as the Inter-professional Spine Assessment and Education Clinics of Ontario [1], to introduce spinal control measurements into routine clinical practice to improve LBP assessment, subgrouping, and individualized treatment planning. REFERENCES: [1] Rampersaud et al., 2014. Spine J., 14(11), S40. [2] Hodges, Cholewicki, van Dieën, 2013. Spinal Control: The Rehabilitation of Back Pain. Churchill Livingstone Elsevier. [3] Bourdon et al., 2018. 8th World Congress of Biomechanics Proceedings, Dublin, Ireland. [4] Zwambag et al., 2018. Ann Biomed Eng., 46(2), 298-309. [5] Ross et al., 2018. MSSE. In Press. [6] Graham et al., 2017. XXVI Congress of the International Society of Biomechanics Proceedings, Brisbane, Australia.

S12.2 Understanding the biology of muscle changes in low back pain and injury: Time dependent mechanisms that modify the capacity of muscle to move and control the spine

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BACKGROUND AND AIM: Muscles are the effector organs of the motor system and the host of several types of sensory receptor. The capacity of muscle to meet the demands place on control of movement and stiffness is a key determinant of function and health of the musculoskeletal system. If a muscle's capacity to generate and sustain force is compromised then the capacity to move and control internal and external forces will be impaired. Structural and functional changes in the trunk muscles are ubiquitous in low back pain and have been observed in acute and chronic phases of the condition, as well as after experimental lesions in animals. The underlying biology is only beginning to be understood.

Methods AND RESULTS: Recent work in humans and animals has probed the cellular and neural mechanisms. These studies reveal a complex interaction between different mechanisms that vary over time. Although muscle atrophy and inhibition of spinal circuits is apparent acutely after injury, the subacute phase is characterised by accumulation of fat and connective tissue (fibrosis) and a transition from slow-to-fast of muscle fibres, but no reduction of muscle size (whole muscle or muscle cells). Recent studies suggest a role for pro-inflammatory cytokines in the muscle (e.g. TNF and IL-1?), which appears to be related to polarisation of macrophages to the pro-inflammatory subtype, particularly within the muscle adipose. This may be secondary to changes in muscle metabolism as a consequence of change sin muscle fibre types. The chronic phase involves more diffuse muscle, fat and connective tissue changes potentially as a result of chronic disuse, and changes in the neural organisation of the motor regions of the brain. Inflammation and fibrosis are highlighted as a major factor in the pathophysiology of many metabolic conditions that are a growing issue in the modern world. Exercise has the potential to target many of these mechanisms but the type of exercise will differ depending on the time-course. Recent work in animals has shown that exercise can reduce the inflammatory response in muscle that occurs in association with spontaneous intervertebral disk pathology.

Conclusions: Together these data show that changes in muscle structure and behaviours have a range of underlying mechanisms that are dynamically regulated over time. These different underlying mechanisms are likely to be ameliorated by exercise, but the approach to exercise will likely dependent on the mechanism.

S12.3 New insights into trunk muscle control in low back pain revealed with high-density surface electromyography

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High density, two-dimensional surface electromyography (EMG) provides a measure of the electric potential distribution over a large surface area during muscle contraction. Unlike classic bipolar surface EMG applications, this method provides a topographical representation of EMG amplitude, and can identify relative adaptations in the intensity of activity within regions of the muscle. Studies utilising high-density EMG have revealed a change in the distribution of activity over the lumbar erector spinae muscle during a fatiguing sustained contraction in asymptomatic individuals as reflected by a shift of the center of activity towards the caudal region of the erector spinae. Likewise, during repeated lifting asymptomatic people display a shift of erector spinae activity towards the caudal region of the muscle. In contrast, high-density EMG investigations have shown that people with chronic low back pain (LBP) fail to engage different regions of their low back muscles when fatigue occurs during both sustained and dynamic contractions. This lack of variability in muscle activation is associated with less variations in accessory (non task-related) angular movement during dynamic contractions which may imply continuous loading on the same muscle structure without variability in the underlying muscle activation pattern. Our recent work has also revealed that an increased redistribution of activity in the erector spinae is associated with greater endurance time suggesting that a variation in activation within regions of the same muscle is potentially relevant to avoid overload of the same muscle fibers during prolonged activation. Thus the redistribution of activity within a muscle appears to reflect an optimal neural strategy to prolong endurance. Collectively, these recent studies reveal novel evidence of neuromuscular adaptations in people with LBP. These studies will be presented.

S12.4 Mapping the nervous system organization and function of trunk muscles in low back pain: insights from brain stimulation and withdrawal reflexes

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Université Laval

Our understanding of how the central nervous system (CNS) controls the trunk muscles and how low back pain (LBP) impacts on this control and organization is scant. Recent developments in the use of electrophysiological techniques including brain and peripheral stimulation have provided a new perspective in the control of trunk muscles and the influence of LBP. Recent work has highlighted; (i) the CNS control of the trunk muscles in humans, and (ii) the influence of LBP on this central control. First, studies using transcranial magnetic stimulation (TMS) targeting trunk muscles in people with and without LBP have provided the first evidence for a role of the primary motor cortex (M1) in the control of trunk muscles, and have shown important differences in M1 organization and function of the trunk-muscle representations in people with LBP. Previous studies showed that people with LBP presented with a different organization of the abdominal- and back-muscle representations in M1. The differences in map organization might be attributed to a different function of the inhibitory/excitatory networks in M1 observed in people with LBP. The differences reported in terms of organization and function of the trunk muscles might explain the different ways people move when they have LBP. Although TMS studies of trunk muscles provide important information about the control of trunk muscles by the CNS, the interpretation remains difficult mainly because of a lack of valid assessment of spinal networks controlling trunk muscles. Second, evaluation of nociceptive withdrawal reflexed has provided a novel way to assess trunk-muscle control by the CNS and the potential involvement of spinal cord networks. Noxious electrical stimulations triggering nociceptive withdrawal reflexes over multiple trunk sites have been used to determine how the CNS protects the trunk from potential injury. We have observed that each trunk muscle presented a unique receptive field that is related to its motor function i.e. the paravertebral muscles were more active after stimulation of the back, and the abdominal muscle were more active by stimulation of the front of the trunk. In addition, the stimulation of each individual site produced a motor strategy that was consistent with a function withdrawal strategy. Our results support a complex and functional organization of the networks controlling the withdrawal reflexes of the trunk. Subsequent work has assessed the trunk withdrawal reflex in people with LBP, which shows a subgroup of people with LBP with reduced response to noxious stimulation of the back muscles and different motor strategies following noxious stimulation. These results extend the current evidence from TMS studies suggesting an important adaptation within the CNS in people with LBP, but that this differs between individuals.

S12.5 Linear and non-linear analysis of individual adaptations during gait in low back pain

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BACKGROUND AND AIM: Walking can be impaired by low back pain (LBP). In acute pain, motor adaptations are thought to protect the painful area from further pain/re-injury. These adaptations have short term benefits (pain relief) but could have long term consequences (e.g. altered tissue loading) if not resolved. Many joints and muscles need to be coordinated to provide smooth biomechanical function to achieve overall stable walking. In this complex system there are no strict rules to which pain adaptations adhere. Detailed description of behavioural (kinematics) adaptations in individuals with LBP that could explain the relation between adaptation strategies and pain persistence is required. Non-linear methods that describe the dynamical nature of pelvis and thorax motion are potential candidates.

Methods AND RESULTS: Recent work has studied the effect of an acute noxious stimulus (e.g. injection of hypertonic saline) on thorax kinematics and the organisation of activity of leg and trunk muscles using muscle synergy analysis. Dynamics of thorax motion were quantified as the local divergence exponent (LDE). LDE reflects the sensitivity to small perturbations that naturally occur during walking (e.g. uneven walking surface), which must be controlled to maintain stable walking. During walking at 0.94 ms-1, compared to walking without pain, acute pain induced 'tighter' organisation of muscle activity that was specific to individuals and increased sensitivity to small perturbations (higher LDE). Findings suggest a more pre-planned and less adaptive/reactive muscle control and could reflect a narrower control that did not deal with small perturbations. Other work investigating pelvis thorax kinematics in chronic LBP suggests greater mechanical coupling of small deviations (variant pattern) between these segments in the horizontal plane compared to pain free controls. Others observed higher coupling of the main kinematics (invariant pattern), i.e. pelvis and thorax move more together in chronic LBP compared to pain free controls.

Conclusions: These findings highlight an individual-specific adaptation to pain in acute (experimental pain) and chronic LBP. To investigate the transition from acute to chronic LBP it is important to investigate the dynamics of pelvis and thorax motion after an acute LBP episode at several time points of recovery. Above findings suggest non-linear analysis that incorporates variant and invariant behaviour could provide further inside into pain adaptations and whether these are linked with transition to chronicity. A candidate non-linear method is recurrence quantification analysis (RQA). RQA assesses the recurrent behaviour of the kinematics using a delay embedding approach (as LDE). This method can be applied separately to pelvis or thorax motion or the coupling and time shift between pelvis and thorax. Such analysis has the potential to understand relationship between kinematics and outcome.

O20 FATIGUE II

O20.1 Muscle electrical activity changes over time during stair ascending until exhaustion

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BACKGROUND AND AIM Non-stop stair ascending at maximum speed is required to reach a safe refuge level from deep underground structures, such as subways and in high-rise buildings in an emergency evacuation situation. Endurance of stair climbing and identifying the time of the onset of leg's local muscle fatigue (LMF) are interests in evacuation research. The objective of this laboratory study was to investigate leg muscles' electromyography (EMG) changes over time during stair ascending until exhaustion on a stair machine.

Methods: The developed muscle activity rate change (MARC) in muscle activity interpretation square (MAIS) was used to evaluate leg LMF at constant step rates equivalent to individual 100% VO2max level. This result is used to validate the MAIS. The MAIS is based on the four assumptions of EMG muscle activity (AMP and MDF) rate change (MARC) over the ascending durations. An increase in AMP and MDF is an indication of: 1) muscle force increase. An increase in AMP and a decrease in MDF is an indication of: 2) muscle fatigue. A decrease in AMP and MDF is an indication of: 3) muscle force decrease. A decrease in AMP and an increase in MDF is an indication of: 4) fatigue recovery. MARC was observed on the both AMP and MDF values of the ten equal length divisions (10%) in the total ascending period (100%). The averages of the MDF and normalized AMP for each equally divided 10% period were calculated for all subjects to yield 1 data point, and totally 10 data points. These 10 periodical average AMP and MDF data points (10-100%) and the changes between the unit times represent the MARC for each muscle during ascension. Later, both the AMP and MDF MARC values are combined to get one final point for each tenth percentile duration and presented into the MAIS, which is used to estimate muscle fatigue.

Results: The appearances of MARC points in the MAISs showed the state of muscle activity changes over time during this predetermined and constant ascending speed at 100% of VO2max on a stair machine. Most of the muscles' MARC points at 90-100% periods were found in the muscle fatigue squares. Moreover, individual AMP and MDF analysis showed significantly increased and decreased, respectively, which supported the interpretations made by the MAIS.

Conclusions: These stair ascending EMG results supported the MARC and MAIS when interpreting muscle fatigue. They seem promising to interpret muscle activity changes per unit time during dynamic tasks over the whole working duration in different activities.

O20.2 Effect of Dynamic Muscle Fatigue on Knee Extensors Maximal Strength and Torque Steadiness in Young and Older Individuals

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BACKGROUND AND AIM: Age-related alterations in neuromuscular function can affect response to muscle fatigue. To date, few studies have investigated the effects of dynamic fatiguing protocols on neuromuscular responses in older individuals. To address this, we investigated the effects of a bout of dynamic fatiguing exercise on maximal strength and isometric torque steadiness of the knee extensors (KE), as well as the associated neural control mechanisms in both young and older healthy individuals.

Methods: Sixteen young (24.9 ± 3.2 years) and 17 older (69.6 ± 3.7 years) volunteers participated. Before and immediately after 22 maximal fatiguing concentric efforts of the KE and knee flexors (KF) at 60°/s, each participant performed: a maximal voluntary isometric contraction (MVIC) of the KE and KF, as well as, a KE constant-torque task (at 20% MVIC). During these tests, the surface EMG signals were simultaneously recorded from the vastus lateralis, rectus femoris, vastus medialis, the long head of the biceps femoris and semitendinosus. The EMG root mean square (RMS) and median frequency (MDF) were estimated over a 1-s epoch corresponding to MVIC and over the middle 12-s corresponding to constant-torque task both pre- and post-fatigue. EMG RMS values recorded during the constant-torque task were normalized to RMS measured for that muscle when acting as an agonist during MVIC pre- and post-fatigue. Torque steadiness was calculated as the coefficient of variation (CV) of the torque, over the same 12-s period used for EMG analysis, pre- and post-fatigue.

Results: As shown in Table 1, fatiguing concentric exercise induced a similar reduction in the MVIC in young and older participants ($p < 0.001$), but the reduction in agonist (i.e. quadriceps) EMG responses (both RMS and MDF) were more pronounced in the young participants (all $p < 0.01$). Torque steadiness also exhibited a similar post-fatigue decrease ($p < 0.05$) in the two groups, but agonist activation and antagonist (i.e. hamstrings) co-activation decreased only in the older participants (all $p < 0.01$). Interestingly, the MDF recorded from the rectus femoris muscle declined more than the other quadriceps muscles after fatiguing exercise ($p < 0.001$).

Conclusions: Fatiguing concentric KE and KF exercise produced similar impairments (%) in maximal torque output and muscle steadiness in young and older individuals. However, different age-related alterations in neural drive to agonist and antagonist muscles were observed.

Table 1: Variables of interest in young and older individuals pre- and post-fatigue

	Pre-Fatigue		Post-Fatigue		Young	Older	Age × Fatigue
	Young	Older	Young	Older	%Diff	%Diff	p value
MVIC							
KE MVIC (Nm)	189.9 ± 50.4	145.5 ± 37.3	161.3 ± 40.8	123.7 ± 32.7	-15.1	-15.0	0.280
EMG MDF (Hz)	77.6 ± 14.5	71.2 ± 12.1	66.9 ± 11.7	65.5 ± 12.5	-13.8	-8.0	**< 0.01**
Agonist activation (RMS, mV)	0.264 ± 0.169	0.172 ± 0.091	0.201 ± 0.139	0.149 ± 0.081	-23.9	-13.4	**< 0.001**
Antagonist co-activation (%)	11.1 ± 6.3	14.8 ± 7.3	8.5 ± 5.7	10.8 ± 6.3	-23.4	-27.0	0.091
Constant-torque task							
Torque steadiness (CV, %)	1.65 ± 0.29	2.21 ± 0.69	1.80 ± 0.25	2.58 ± 0.74	9.1	16.7	0.260
EMG MDF (Hz)	70.2 ± 13.9	70.7 ± 15.8	63.4 ± 10.3	62.8 ± 12.3	-9.7	-11.2	0.384
Agonist activation (%)	15.0 ± 6.0	21.3 ± 8.7	15.4 ± 6.9	18.9 ± 8.3	2.7	-11.3	**< 0.05**
Antagonist co-activation (%)	1.75 ± 1.10	3.40 ± 1.94	1.55 ± 1.15	2.75 ± 1.61	-11.4	-19.1	**< 0.05**

Values are means ± SD. Agonist activation and MDF are presented as the average of the three quadriceps muscles (vastus lateralis, rectus femoris & vastus medialis); antagonist co-activation is presented as the average of the two hamstring muscles (biceps femoris & semitendinosus). n = number of participants; %Diff = percentage change after fatigue; Age × Fatigue = Interaction effect between age (young vs. older) and fatigue (pre- vs. post-fatiguing exercise)

O20.3 Postural position sequences correlate to perceived pain and fatigue

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Background and Aim: Office workers report significant discomfort, particularly in the neck, back and shoulders when performing sedentary office work. Musculoskeletal Disorder (MSD) risk factors include extreme and prolonged static postures; some other MSD contributing factors remain uncertain. Postural changes are recommended at least every 30 minutes, without reducing productivity. Statistically significant information was found when matching postural deviation patterns with high and low perceived back and neck pain, and fatigue. Since these perceptions are known MSD precursors, postural deviation patterns could be key.

Methods: Ten working aged adults volunteered for one-hour data entry tasks wearing wireless 2D inclinometers on the head and upper back to capture accurate deviations recorded during tasks using three workstations: a seated desk and two desks that automatically alternated between standing and seated heights. Standing lasted 6 or 9 minutes of a 20 minute cycle. Following each recording, participants reported perceived back pain, neck pain and fatigue on a 10 cm Visual Analogue Scale indicating the degree of agreement of each value for each participant and workstation. Postural deviation was discretized into levels in sagittal (based on the Rapid Upper Limb Assessment) and frontal (based on Keyserling) planes. Sagittal head deviation level changed at -5°, 10°, and 20°, and back at -5°, 10°, 20°, and 60°. Head and back frontal deviations changed at -10°, -2°, 2°, and 10°. Postural sequences of 4 consecutive state levels were tracked for each plane, each workstation, and each participant. These are termed "postural gestures" and capture the dynamic sequence of motion within a plane. Perception values were discretized into 5 intensities, each containing 1/5 of the observations for a given feature and together covering the range of values observed for that feature. An "absent" and "present" category was established for each perceptual feature based on the greatest difference between adjacent quintiles.

Results: Postural sequences that occur with statistically significant difference in frequency between "absent" and "present" quintiles were identified using a χ^2 difference of proportions, and those gestures common to the entire set of participants were identified. Between 8 and 23 postural sequences were found for each of "absent" and "present" perceptions of neck pain, back pain and fatigue. These differences may indicate postural behaviour that increases risk or protects from pain or fatigue. All of the 81 significant postural gestures which occurred for all participants, only occurred when using sit-stand workstations. 83% of those occurred in the frontal plane with similar numbers for neck pain, back pain and fatigue.

Conclusions: This combination of perceived and objective measurements with statistical recognition methods allows exploration of links between postural gesture patterns and perceived MSD risk indicators.

O20.4 Central and peripheral fatigue affects maximal, but not submaximal, rate of force development in runners

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BACKGROUND AND AIM: Rate of force development (RFD) is considered an important muscle strength parameter, especially for athletes in sports requiring brief fast contractions (e.g. running). In a series of fast force pulses performed across a range of submaximal values, for each pulse there is a linear relationship between the force peak and the RFD peak. The slope of this relationship is termed RFD scaling factor (RFD-SF). RFD-SF quantifies the extent to which RFD scales with the intensity of the contraction. This study investigated the effect of central and peripheral fatigue induced by endurance running on the RFD-SF of knee extensors.

Methods: Twenty-six male amateur runners (aged 20 to 55 years) were evaluated before and immediately after a half-marathon race. Knee extensors maximal voluntary isometric contractions (MVC) were recorded and the RFD-SF protocol was adopted. Electrically doublet stimuli were delivered during MVC and at rest to calculate the level of voluntary activation and of contractile capacity.

Results: Participants showed a decrease in: voluntary activation (-9%, $p<0.01$), resting doublet twitch (-10%, $p<0.01$), maximal force (-18%, $p<0.01$), and maximal RFD (-20%, $p<0.01$). Nevertheless, slope and intercept of RFD-SF regression were unaffected by the race ($p > 0.6$). The RFD of pulses up to 60% of MVC were largely unaffected by the race (all p values > 0.4).

Conclusions: The half-marathon induced a considerable amount of central and peripheral fatigue and a decrease of maximal RFD. Surprisingly, the RFD-SF was unaffected by fatigue. Thus, for a wide range of submaximal intensities (up to 60% of MVC) the rapid force capacity was not affected by fatigue. Consequently, investigating the RFD in maximal and submaximal contractions do not provided comparable results. Since submaximal contractions are more specific for runners, this work underlines the relevance of measuring RFD in submaximal rapid contractions since adopting maximal contractions may overestimate the loss of explosive strength induced by the run.

O20.5 Additional Insight Into Biarticular Muscle Function: The Influence Of Hip Flexor Fatigue On Rectus Femoris Activity At The Knee

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BACKGROUND AND AIM: Recent evidence suggests that rectus femoris activity may be greater at its proximal end during hip flexion and at the distal end during knee extension. It is still unclear, however, if fatigue at one end of a biarticular muscle affects the opposite end. We sought to examine the effects of hip flexion fatigue on peak torque and vastus lateralis and rectus femoris electromyographic (EMG) amplitude during maximal contractions of the knee extensors. A secondary purpose was to evaluate how rectus femoris muscle length influenced these responses.

METHODS: Eleven men (age = 23 years) visited the laboratory on three occasions, the first of which was for familiarization. All visits were at the same time of day, and subjects refrained from exercise. Bipolar surface EMG signals were detected from the vastus lateralis and five sites along the length of the rectus femoris (proximal, proximal/mid, mid, mid/distal, and distal). Testing was performed in the supine position (i.e., hip extended). Subjects performed maximal voluntary isometric contractions (MVICs) of the dominant knee extensors at a joint angle of 70°. Thereafter, they performed 50 maximal concentric hip flexions with the knee extended or at 70°. Following the hip fatigue protocol, the subjects performed a final knee extensor MVIC. Peak torque and vastus lateralis EMG amplitude were evaluated with two-way (knee angle during the fatigue protocol × time) analyses of variance (ANOVAs). Rectus femoris EMG amplitude was examined with a three-way (sensor × knee angle × time) ANOVA.

RESULTS: With the knee extended, the mean ± SD pre-fatigue and post-fatigue peak torque values were 279.2 ± 39.3 and 279.1 ± 48.0 Nm, respectively. The corresponding values for the trial with the knee at a 70° joint angle were 280.8 ± 38.1 and 281.9 ± 48.2 Nm. There was no interaction ($p = .876$) and no main effects for knee angle ($p = .804$) or time ($p = .951$). In contrast, both vastus lateralis and rectus femoris EMG amplitude showed significant main effects for time. For the vastus lateralis, hip flexor fatigue resulted in significant increases in EMG amplitude (pre and post marginal means = 173.2 and 217.9 μV root-mean-squared, respectively), whereas rectus femoris activity was suppressed (pre and post marginal means = 214.4 and 154.7 μV root-mean-squared, respectively). Although the EMG amplitude tended to be highest in the middle of the rectus femoris, there was no main effect for sensor ($p = .133$). Many of our findings were supported by individual subject data points exceeding minimal difference values.

CONCLUSIONS: In contrast to our hypotheses, these data indicate that fatigue of the hip flexors did not affect knee extensor strength, but altered the voluntary control of the vastus lateralis and rectus femoris. The increase in vastus lateralis EMG amplitude may be indicative of a mechanism to preserve force characteristics at a joint despite decreased contributions from other synergist muscles.

O20.6 The central nervous system adapts toward a more balanced force distribution between synergist muscles during a fatiguing task

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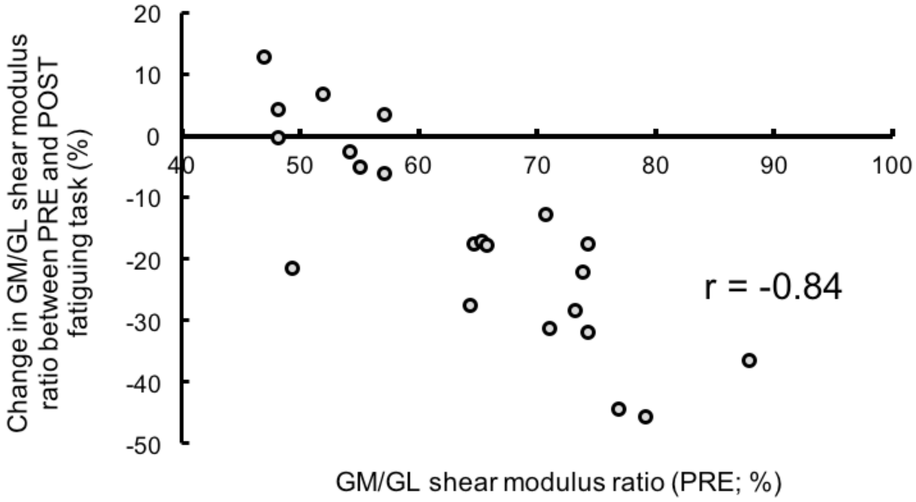
BACKGROUND AND AIM: The redundancy of the musculoskeletal system implies that a given joint moment can be produced by different coordination strategies (i.e., distribution of force among individual muscles). Recent studies report a large inter-individual variability in the distribution of activation/force among individual muscles, even during simple tasks. The way these coordination strategies adapt to muscle fatigue is unclear. The aim of this study was to determine whether the distribution of force among synergist muscles adapts throughout a sustained isometric contraction performed until to task failure. We took advantage of elastography to account for both passive and active muscle force, allowing us to provide an index of change in the distribution of force during the fatiguing task. This study was performed on two pairs of synergist muscles [vastus lateralis (VL) and medialis (VM) for the quadriceps and gastrocnemius lateralis (GL) and medialis (GM) for the triceps surae].

METHODS: Twenty-two healthy volunteers participated in this study. Two identical experiments were conducted on two separate days, either on the vastii or on the gastrocnemii, in a random order. The experimental sessions consisted in single-joint tasks performed with the dominant leg [isometric knee extension or plantar flexion at 25% of maximal voluntary contraction (MVC)]. At the end of each experimental session, the participants performed a sustained isometric contraction at 25% of MVC until to task failure. For each muscle group, the shear modulus (an index of individual muscle force) of the two muscles sharing the same functions was collected before (PRE) and during the fatiguing task. The change in the distribution of force among the synergist muscles was considered through the calculation of the following shear modulus ratios: VM/VL and GM/GL. For each shear modulus ratio [VM/VL and GM/GL], a repeated-measures analysis of variance (ANOVA) was used to determine if there were differences between time [PRE vs. POST (last measurement before task failure)]. To quantify the inter-individual variability of the adaptation in the distribution of force during the fatiguing task (change in the ratios between PRE and POST), we determined the relationship between this change and the distribution of force measured without fatigue (PRE) using Pearson's correlation coefficient.

RESULTS: The average duration of the fatiguing task was 169±61 and 527±211 s, for the knee extension and plantar flexion, respectively. The ANOVA revealed a significant effect of time on shear modulus ratio ($P=0.004$). Specifically, the shear modulus ratio of GM/GL was significantly lower at the end of the fatiguing task (47.7±9.1%) compared to PRE (64.1±11.7%; $P<0.001$), while no difference was found for the VL/VM ratio ($P=0.490$). In addition, a strong negative correlation was found between GM/GL ratio without fatigue (PRE) and the changes in the GM/GL ratio between PRE and POST ($r = -0.84$) (figure 1).

CONCLUSIONS: Overall, this study provides evidence that the central nervous system adapts toward a more balanced force distribution between synergists muscle during a fatiguing task. This adaptation is strongly related to the balance of activation distribution without fatigue. Interestingly it was only observed for the triceps surae suggesting that disassociation of drive between the two vastii is difficult or at high cost for the nervous system. Further work is needed to determine the origin of this different adaptation and its potential consequences on the musculoskeletal system.


Change in GM/GL shear modulus ratio between PRE and POST fatiguing task (%)
20
10
0
-10
-20
-30
-40
-50
40
50
60
70
80
90
100
r = -0.84
GM/GL shear modulus ratio (PRE; %)

O21 GAIT & POSTURE III

O21.1 Extraction of the principal EMG-activations in 100 children during gait: analysis of rectus femoris and vastus medialis

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BACKGROUND AND AIM: Although surface electromyography (EMG) is a powerful tool in clinical gait analysis and sport science, its widespread use is limited by the difficulty to provide a correct and compact signal interpretation in dynamic conditions. In cyclic movements, such as walking or running, the number of EMG activations and the onset-offset timing patterns typically changes from cycle to cycle. Nevertheless, it is possible to define principal EMG-activations as those activations necessary to successfully perform the specific cyclic task. They are indispensable activations and are predominantly present in all cycles. By contrast, secondary activations are defined as those activations needed to correct unexpected disturbs of motion or balance. The aim of this study is to reprocess EMG gait signals of rectus femoris and vastus medialis from a database of 100 typically developing children restricting the study to principal activations only. We hypothesize that this approach could allow for a remarkable simplification of results, providing a novel set of normative EMG activation patterns of simpler interpretation and of interest for clinicians.

Methods: We retrospectively analyzed the database of children (6.5-11.5 years) that walked overground, at self-selected pace. For each child, principal EMG-activations were extracted using clustering [1].
Results over the population are represented reporting the number of children showing principal activations in each percent of the gait cycle.

Results: For the rectus femoris muscle, the great majority of the population (from 75% up to 93% of children) shows a principal activation at load response, between 0% and 8% of the gait cycle (GC) and in terminal swing, between 94% and 100% GC. In addition, from 20% up to 36% of children show a principal activation between 50% and 60% GC, probably aimed at stabilizing the hip joint in preparation to the single limb support. For the vastus lateralis, the great majority of children (from 75% up to 96%) show a principal activation at load response, between 0% and 8% GC and in terminal swing, between 91% and 100% GC. The data were also analyzed separately for children of different ages (class ranges: 6.5-8.5 years, 8.5-10 years, 10-11.5 years). The only noticeable difference was the reduction of the number of children showing rectus femoris principal activation in preparation to swing in the older children class.

Conclusion: This study demonstrated that the extraction of the principal EMG-activations may provide compact and useful information to describe both a single subject and a population. This might be valuable in clinics and sport science in the outcome evaluation pre/post a therapeutic, rehabilitation or training protocol.

References 1. Rosati et al., Muscle activation patterns during gait: A hierarchical clustering analysis. Biomed Sig Proc Control 2017, 31, 463-469, doi:10.1016/j.bspc.2016.09.017

O21.2 Are older adults able to modify anticipatory postural adjustments following balance perturbations in gait initiation?

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BACKGROUND: The anticipatory phase of gait initiation challenges head stabilization in older individuals and represents a transient phase during which falls are likely to be provoked (Laudani et al. J Electromyogr Kinesiol, 2006). Despite anticipatory postural adjustments (APAs) are thought to be immutable once released, young adults are able to modify them online and compensate for unexpected waist-pulling perturbations in step initiation (Mouchnino et al. Gait Posture, 2012). The aim of the study was to investigate the ability of older adults to modify online both APAs and upper body motion in order to preserve head stability and balance in response to unexpected waist perturbations during gait initiation.

Methods: Eight young (24±1 yrs) and eight older women (72±4 yrs) initiated locomotion while a lateral force was applied to the pelvis to unexpectedly perturb posture during the anticipatory phase of gait initiation. Two force plates (Kistler) were used to evaluate the centre of pressure (CoP) displacement. A motion analysis system (VICON) was used to assess angular displacement of the upper body segments via a Plug-in-Gait marker placement model. Principal component analysis of angular displacement waveforms was used to summarise the most common patterns of head and trunk motion in the sagittal and frontal planes. Effects of age (young vs older) and perturbation (with vs without) on the CoP anticipatory displacement and first step execution were tested via a mixed two-way ANOVA (? = 0.05).

Results: Older displayed lower increase in lateral displacement of CoP during perturbed trials relative to unperturbed ones with respect to young (+10% and +21%, respectively). Duration of APAs was higher during perturbed than unperturbed trials in young only (+109 ms). Both age groups took a shorter and wider first step during perturbed than unperturbed trials, with older showing a greater reduction in step length compared to young (-40% and -18%, respectively). Young responded to perturbation by leaning forward both trunk and head, while older showed a characteristic pattern involving delayed forward lean of trunk and upward roll of head. Both head and trunk tilted medially in response to the lateral perturbation in both age groups, with the head returning to neutral position by the end of the first step in young only.

Conclusions: Online modification, i.e. increased duration, of APAs in response to unexpected waist perturbations during gait initiation was observed in young but not in older women. In addition, the delayed head-on-trunk motion in older compared to young women could undermine head stability in both sagittal and frontal planes, thus potentially increasing the risk of falling. Overall, these changes in APAs resulted in greater reduction of the first step length in older than young women, outlining an age-related inability to initiate forward locomotion through appropriate stepping execution in response to unexpected balance perturbations.

O21.3 Walking with visual perturbations but not an attention-dividing task modulates muscle coactivation patterns in old adults

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BACKGROUND AND AIM: Old adults walk with more coactivation of their agonist and antagonist leg muscles than young adults. As aging leads to higher risk of falls, it is thought that old adults adopt this strategy as a neuromuscular means to preserve balance. By contracting muscles with opposing joint actions, old adults increase the stiffness of their leg joints, which may mitigate the effect of disturbances on movement patterns. However, it is unclear to what extent coactivation may be modulated by environmental factors which may compromise the balance of old adults. The purpose of this study was to compare how visual processing and attention-dividing tasks affect lower limb coactivation during treadmill walking in old and young adults.

Methods: 16 healthy old adults (70±4 yrs) and 12 young adults (24±4 yrs) walked on a treadmill at their preferred overground speed while watching a speed-matched virtual reality hallway. Three separate 3-min walking trials were presented: 1) Unperturbed walking with no cognitive dual-task (Normal), 2) walking while performing serial 7 subtractions (Dual-task), and 3) walking with the visual perception of lateral instability - i.e. continuous mediolateral hallway oscillations (Visual Perturbation). We collected (2 kHz) surface electromyography (EMG) bilaterally from the medial hamstrings (MH), vastus lateralis (VL), medial gastrocnemius (MG), soleus (SL), and tibialis anterior (TA). EMG was bandpass filtered (1-350 Hz), rectified, and envelope filtered (10 Hz). EMG was normalized to time (1000 points/stride) and amplitude (RMS voltage), then ensemble averaged across the gait cycle. We calculated coactivation for 3 agonist-antagonist muscle pairs (MH-VL, MG-TA, SL-TA) using Rudolph's coactivation indices. A 2-way mixed ANOVA compared differences in mean coactivation index between age and condition within the gait cycle.

Results: For unperturbed walking, coactivation in old adults was greater than young adults across the entire stride (MH-VL: +23.3%, $p = 0.035$; MG-TA: +31.8%, $p = 0.023$). Young adults exhibited no significant increases in coactivation from normal when walking in dual-task or visual pertubation conditions. Old adults exhibited no increases during dual-task walking. However when presented with visual perturbations, only old adults significantly elevated coactivation for all muscle pairs (MH-VL +26.5%, $p = 0.018$; MG-TA +28.9%, $p = 0.002$; SL-TA +30.9%, $p = 0.001$).

Conclusions: Old adults walked with greater antagonist muscle coactivation than young adults, and this between-group difference was amplified in the presence of visual perturbations (Fig 1). We conjecture coactivation is an automatic neuromuscular response to visual perception of instability. We've previously shown kinematic variability and local stability increases during these visual perturbations, though it is less clear if coactivation causes instability or reflects a protective mechanism to counteract instability and prevent falls.

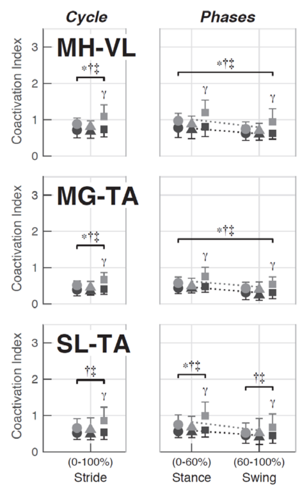

Figure 1. Coactivation indices for the young and older adults during all walking conditions by segments of the gait cycle (mean ± s.d.). Significant age effects denoted by ⁎. Significant condition effects denoted by †. Significant interactions between age and within conditions denoted by ‡. Significant differences in the visual perturbation condition from normal within the older adults denoted by γ. The older adults had no significant differences from normal in the cognitive task condition. For the young adults, there were no significant differences from normal for any conditions.

Age groups: Older Adults; Young Adults
Walking conditions: ○ Normal; △ Dual-Task; □ Visual

O21.4 A Strong Medial-Lateral and Anterior-Posterior Coupling During Single-Leg Stance is Related to Muscle Activity Modulation in Seniors

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AIM: Age- specific comparisons of ankle muscle envelope modulation revealed differences in children and adults as compared with seniors. Compared with side-by-side standing, a different demand on frontal plane stability is to be expected during single-leg standing. The objective of this study was to estimate the age-dependent coupling of anterior-posterior and medial-lateral directions while standing on one leg. The second aim was to relate the amount of absolute differences between both directions to the ankle muscle envelope modulation.

METHODS: Children (age: 9-10 years, m/f: 10/9), adults (age: 20-25 years, m/f: 20/10) and seniors (age: 53-79 years, m/f: 16/13) performed a single-leg stance on their dominant leg on a force plate (GK-1000, sampling rate: 40 Hz) for exactly 30 seconds. To account for anthropometric differences, the mean center of pressure (COP) velocities in medial-lateral (x) and anterior-posterior (y) directions were normalized by participants' body moment of inertia. Surface EMG of two lower limb muscles (tibialis anterior, TA; soleus, SO) was captured (IMAGO, sampling rate: 1000 Hz) and quantified as the degree of modulation in muscle activity (coefficient of variation of the EMG envelope). Age- group effects on normalized COP velocities, ankle muscle modulation and absolute x-y differences were computed using univariate analyses of variance. Age-group specific linear regression analyses were applied to examine the amount of coupling between both COP directions and the relationship of absolute x-y differences with TA or SO envelope modulation.

RESULTS: There were large effects of age- group ($P < 0.001$) on results of both COP directions (x: $F = 141.7$, $\eta p2 = 0.79$, y: $F = 136.8$, $\eta p2 = 0.79$) as well as normalized x-y differences ($F = 18.7$, $\eta p2 = 0.34$) with the known u-shaped fashion. The results of both ankle muscles revealed age- group effects (TA: $F = 9.2$, $\eta p2 = 0.20$, SO: $F = 5.6$, $\eta p2 = 0.13$, $P < 0.01$) as well. The normalized COP velocities were positively associated in all age- groups (children: $r = 0.74$, adults: $r = 0.67$, seniors: $r = 0.84$, $P < 0.001$). By contrast, x-y differences were negatively associated with TA modulation in seniors only (children: $r = 0.20$, $P > 0.4$; adults: $r = -0.18$, $P > 0.3$; seniors: $r = -0.63$, $P < 0.001$). SO envelope modulation was not related to x-y differences of normalized COP velocities (children: $r = 0.11$, adults: $r = -0.09$, seniors: $r = 0.02$, $P > 0.6$).

CONCLUSION: Higher correlation coefficients of COPx and COPy directions in seniors mimic a more constrained and a less automatic mode of balance control. This limited independent control of both directions might reflect less efficient control of single-leg stance in seniors, which is negatively related to TA envelope modulation.

O21.5 Exploring sEMG-based biomarkers to detect early signs of sarcopenia: age-specific differences in the time-frequency representation of SEMG data recorded during a submaximal cyclic back extension exercise

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Aim: Motivated by the goal of developing new methods to detect early signs of sarcopenia, we investigated if surface electromyographic (SEMG) data recorded during the performance of cyclic, submaximal back extensions are marked by age-specific differences in their time and frequency characteristics.

Methods: 86 healthy volunteers used a back dynamometer to perform first a series of three maximal voluntary contractions (MVC) consisting of isometric back extensions, then an isometric back extension at 80% MVC, and finally 25 slow cyclic back extensions at 50% MVC. SEMG data was recorded bilaterally at L1, L2, and L5 from the iliocostalis lumborum, longissimus, and multifidus muscles, respectively. Two-factorial ANOVA's were performed to investigate age-specific differences in both the initial value and the time-course (as defined by the slope of the regression line) of the root mean square (RMS-SEMG) values and instantaneous median frequency (IMDF-SEMG) values calculated separately for the shortening and lengthening phases of the exercise cycles.

Results: Back extensor strength was comparable in younger and older adults. The initial value of RMS-SEMG and IMDF-SEMG as well as the RMS-SEMG time-course did not significantly differ between the two age groups. Conversely, the IMDF-SEMG time-course showed more rapid changes in younger than in older individuals. Absolute and relative reliability of the SEMG time-frequency representations were comparable in older and younger individuals with good to excellent relative reliability but variable absolute variability levels.

Conclusions: The IMDF-SEMG time-course derived from submaximal, cyclic back extension exercises performed at moderate effort showed significant differences in younger vs. older adults despite back extension strength was found to be comparable in the two age groups. We conclude that the SEMG method proposed in this study has great potential for being used as a biomarker to detect early signs of sarcopenic back muscle function.

O21.6 Muscular activation in vibration perturbed human walking

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Background and Aim: Walking on vibrating floor causes a complex exposure pattern and the superimposition of walk and vibration may induce changes in neuromuscular control [1]. The problem is relevant is many field, as sea platform or railway transports. The present study investigates the leg muscular activation and stride phases during walking under vibration to derive a muscle model in these circumstances.

Methods: Ten male subjects walked on a treadmill positioned on a 6-DOF vibrating table. Vibration was imposed at four frequencies (4, 8, 12, 16 Hz) along vertical and transversal direction. Walking speed was set at 1.25 m/s. Surface electromyography (sEMG) of four muscles was recorded on both lower limbs using linear arrays of four electrodes. Stride phases were recorded using accelerometers and stride length was calculated. All measurements were normalized to the walking condition without the vibration.

Results: Preliminary results showed that vibration does not affect stride length and step phases. The muscular activation patterns exhibit frequency related modification, in terms of sEMG bursts amplitude and timing. At 8Hz, sEMG amplitude increased linearly over time on three out of four muscles.

Discussion: Transmitted vibration triggers a tonic vibration reflex (TVR) that is related to mechanical frequencies [2]. TVR is also related to the motor task because of the mechanical coupling between vibrator and biological apparatus [3]. These facts could explain the modifications in leg muscle activation revealed with sEMG. 1. Fattorini L, Tirabasso A, Lunghi A, Di Giovanni R, Sacco F, Marchetti E (2016). Muscular forearm activation in hand-grip tasks with superimposition of mechanical vibrations. J Electromyogr Kinesiol, (26), pg 143-148 2. Eklund G, Hagbarth KE (1966). Normal variability of tonic vibration reflexes in man. Exp Neurol, (16), pg. 80-92 3. Fattorini L, Tirabasso A, Lunghi A, Di Giovanni R, Sacco F, Marchetti E (2017). Muscular synchronization and hand-arm fatigue. Int J Ind Ergon.

O22 MYOELECTRIC CONTROL

O22.1 Improving two-channel myoelectric control performance through spatial information enhancement

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Introduction: Myoelectric control based on pattern recognition (PR) is able to provide intuitive control over multiple degree of freedoms (DOFs) of powered prostheses. As the potential merits it presents, studies have been performed to improve its daily use performance by applying advanced signal processing algorithms and effective experiment setup [1]. Among these factors, physical channel number is a crucial one for the control performance would generally be improved with its increase. Most myoelectric studies adopted 4 to 8 electromyography (EMG) channels. However, from the perspective of practical applications, the complexity of the system would be reduced with the decrease in the number of physical channels, making it easy to deploy, as well as reducing the power consumption and extending the operation time. As the decrease of channels would deteriorate the control performance, we intended to investigate systematically how to maintain PR-based myoelectric control performance while using only two physical channels.

Methods: This study proposed to improve the control performance of the two-channel myoelectric system through exploiting its spatial information, using the combination of the optimal position and virtual channel (VC) technique. All possible 15 two-electrode combinations out of six electrodes were considered for the effect of electrode position. Meanwhile, two VCs were formed by making either the average of or the difference between two physical channels. Three subsets of electrode pairs were selected for each subject, the subsets with the worst and best performance of the group without VC (WS and BS), and the subset with the best performance of the group with VC (BVS), to investigate the improvement from the combination of optimal electrode position and VC.

Results: The error rate averaged across the electrode combination was $17.51 \pm 2.81\%$ for the group without VCs, and $10.15 \pm 1.60\%$ for the group with VCs (Fig. 1a). It was indicated that the classification performance was significantly improved with the inclusion of VCs ($p < 0.05$), and its effect was not influenced by electrode positions. Further, as shown in Fig 1b, the performance of the BVS with VC was significantly better than that of BS ($p < 0.05$). The latter was significantly better than that of WS ($p < 0.05$).

Conclusion: This study investigated the case of two-channel myoelectric control and proposed to improve its performance through the combination of optimizing the electrode position and inclusion of two virtual channels. The results highlighted the importance of exploiting the spatial information in PR-based myoelectric control with a small number of electrodes, and revealed its potential in practical application.

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O22.2 Myo-ART: A surface EMG augmented reality tool

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BACKGROUND AND AIM: Augmented Reality is a real-time technology allowing superimposing information coming from the real world and information acquired and elaborated by a computer. Augmented Reality has been proved successful in several applications ranging from laparoscopic surgical training [1] to balance and mobility rehabilitation in the elderly [2] and Parkinson's disease [3]. The aim of this work was the design and development of an Augmented Reality system allowing the visualization of information about muscle activity superimposed to the detection system over the investigated muscle.

Methods: The system architecture (Figure) includes: 1) a video camera (eventually integrated into a smartphone or tablet or into smartglasses), 2) one or more sEMG detection systems (both bipolar and mono or bi-dimensional arrays of electrodes), 3) one or more sEMG acquisition systems, 4) a processing and visualization unit. The processing unit receives the video frames from the video camera and the sEMG signals from the acquisition systems. The processing unit performs the following steps: 1. Processes the video frame received by the video camera, identifying the presence of EMG detection systems inside the frame. 2. For each sEMG acquisition system, calculates the ARV value of the sEMG signal epoch corresponding to the current video frame, 3. Creates an augmented video frame adding, to the original video frame, the information about sEMG activity by coloring the detection systems, identified at step 1, with a color (or color map in case of mono or bi-dimensional arrays) representative of the ARV value (or ARV distribution): for example blue means a low EMG activity while red means a high EMG activity. 4. Show the augmented frame on a display (monitor, tablet or smartglasses). The software has been developed using the Artoolkit toolbox (v.5.3.2) and Qt libraries.

Results: The developed system works with either bipolar (Due, OTbioelettronica and LISiN) or multi-channel EMG systems (32 channel wearable acquisition system developed by LISiN). The software can run 1) on a PC using a webcam for video capture and showing the augmented video on a standard monitor, 2) on a tablet (Android Operating System) using the integrated camera or 3) on the Epson Moverio BT-300 smartglasses using the see-through modality (Figure).

Conclusions: An augmented reality system visualizing the information about muscle activity superimposed to the detection systems has been developed. The system is currently under validation as an augmented biofeedback in sport and rehabilitation fields in order to verify advantages with respect to a standard biofeedback. REFERENCES: 1 E. Z. Barsom et al. Surg. Endosc. 2016. 2 Dal Jae Im et al. Ann. Rehabil. Med. 2015. 3 M.R.C. Van den Heuvel et al. Parkinsonism and Related Disorders, 2014.

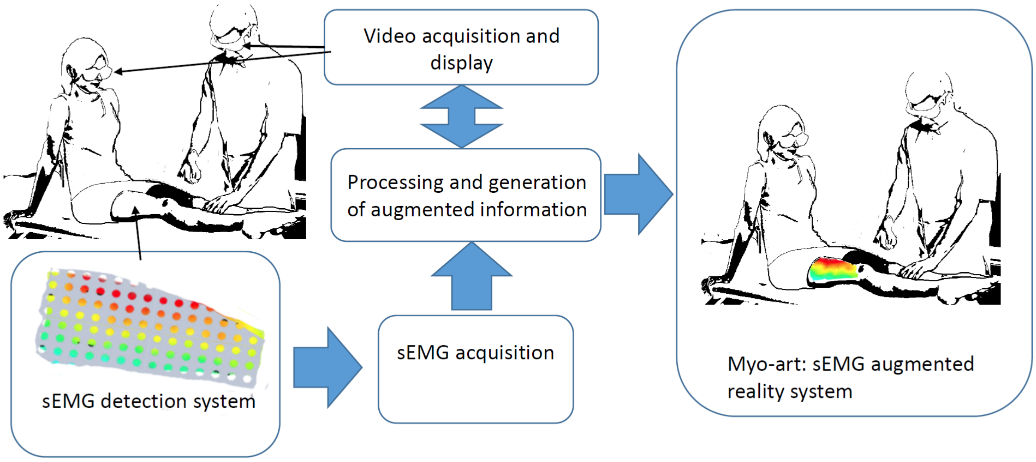

Figure: block diagram of the sEMG augmented reality system in the case of smart-glasses use. The video acquisition, processing and visualization of augmented information are all integrated into the smart-glasses. sEMG signals are transmitted to the smart-glasses via Bluetooth or Wi-Fi

O22.3 Motor Unit Drive (MU Drive) Improves Over Myoelectric Signals for Upper-limb Prosthetic Control

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BACKGROUND AND AIM: Modern prosthetic limbs have made strident gains in recent years, incorporating terminal electromechanical devices that are capable of mimicking the human hand with multi-articulated grasps and coordinated movement. But people with limb loss have been prevented from accessing these advanced control capabilities because the fundamental technology used to interface the prosthesis with the nervous system has not changed for nearly 5 decades. Consequently, among the 41,000 people in the US with traumatic or congenital limb loss, nearly 23-35% abandon regular use of their myoelectric prosthesis.

Methods: To meet the immediate healthcare need of amputees, we are developing advanced algorithms that measure motor unit (MU) activity in real-time from surface electromyographic (sEMG) signals recorded from residual muscles of the amputated or congenitally missing limb, and transform the extracted firings into motor unit drive (MU Drive) control signals that can be used to drive an upper-limb prosthesis. We analyzed the control characteristics of the MU Drive signal and compared it with conventional amplitude-based (RMS) myoelectric control signals in a series of experiments involving (n=10) control subjects and (n=13) subjects with congenital and traumatic trans-radial limb-loss. sEMG signals were recorded from the extensor digitorum, flexor digitorum profundus, biceps brachii and pronator teres muscles using the dEMG acquisition system (Delsys Inc,, Natick, MA). For the control subjects, a custom designed data-glove with Trigno? Wireless goniometers, load cells and IMU sensors (Delsys Inc, Natick, MA) was used to measure force and movement of the fingers and forearm during voluntary flexion/extension of the fingers, object grasping and supination/ pronation of the forearm. Amputee subjects were instructed to attempt the same intended movements of their missing and residual limb facilitated by bilateral mirrored movements of their intact limb.

Results: We observed three major improvements in the control characteristics of MU Drive over conventional RMS myoelectric control signals: 1) MU Drive provides a greater dynamic range of control whereas the RMS myoelectric signal was limited in range by the electronic noise; 2) MU Drive provides smoother proportional increases and decreases in control with significantly less variability than the RMS myoelectric signal; and 3) MU Drive control signals are more closely related to the intended output movement of the intact limb.

Conclusions: These results demonstrate first-time, implementation of non-invasive sensors and real-time algorithms for translating the motor unit firings to high-fidelity prosthetic control signals. This innovation holds promise for improving the sense of embodiment, increasing function, and ultimately reducing prosthesis rejection for people with limb loss while maintaining lower costs and reduced risks than implantable alternatives.

O22.4 Adapting Myoelectric Pattern Recognition in a Virtual Environment

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Shirley Ryan AbilityLab

BACKGROUND AND AIM: Major upper-limb amputation impacts hundreds of thousands of individuals world-wide. Myoelectric prostheses, devices which are controlled using the electrical signal produced by contracting muscle, have advanced steadily since their introduction and are used to restore function to amputees. Pattern recognition (PR) is often used in conjunction with myoelectric prostheses as it allows users to naturally contract their muscles while performing control contractions (e.g. hand open or wrist flexion). However, PR systems require a set of algorithmic training data that are often collected when the residual limb is held in a neutral position, which is not representative of real-world use where the patient moves their limb to accomplish functional tasks.

Methods: Using a commercially available virtual reality system (HTC Vive) and our custom electromyography (EMG) armband, we have developed an immersive virtual environment to assist users in collecting more representative algorithmic training data. The technical development comprises of: 1. A new virtual outcome measure test. We introduce here a 3D version of the target achievement control (TAC) outcome measures test, which has been previously presented in 2D by our group (Simon et al. 2011). The 3D version requires the user to perform, in real-time, a pseudo-randomly selected control contraction which was previously trained, while also requiring them to orientate their limb into one of three positions: -45° (arm pointing towards ground), 0° (arm parallel with ground), and +45° (arm pointing upwards). 2. A serious game which encourages the user to orientate their arm into a variety of positions to destroy virtual cubes corresponding to a specific control contraction. The EMG information used to destroy said cubes is used in a real-time adaptation algorithm to improve classification. Fourteen subjects (seven control and seven treatment) collected EMG data with their limb in a neutral position. Following collection, the subjects performed the 3D TAC test where their completion rate (number of control contractions successfully achieved) and completion time (time taken to complete the task) were recorded as a baseline. All subjects then performed the serious game (albeit only the treatment subjects had EMG adaptation applied), followed by the TAC test once more.

Results: Our preliminary results found that the treatment subject's completion rate increased by 33.33% and completion time decreased by 12.38% following adaptation, whereas control subjects saw an increase of 17.71% and decrease of 4.91% for completion rate and time, respectively.

Conclusions: These results suggest that by adapting with additional dynamic limb information can have substantial improvements in real-time myoelectric control. Simon, A.M. et al., 2011. The Target Achievement Control Test: Evaluating real-time myoelectric pattern recognition control of a multifunctional upper-limb prosthesis. Journal of Rehabilitation

O22.5 Reachy, a 3D-printed human-like robotic arm as a test bed for prosthesis control strategies

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BACKGROUND & AIM: Elaborating efficient control strategies is still a key challenge for the design of robotic arm prostheses and requires thorough testing prior to integration on an actual prosthesis. Such testing can take place in an immersive simulated setup thanks to virtual reality, or be performed on an actual robotic arm. However, for the sake of consistency with prosthetic applications, employing an actual robot requires it to show human-like features, a constraint making most industrial-grade robots unsuitable. To fulfill this need for a biomimetic test platform, we present a human-like robotic arm that can emulate a prosthesis for testing purpose. This robot's design focuses on versatility by enabling easy interfacing and quick morphological modification thanks to its open-source and open-hardware architecture.

Methods: Reachy is a 3D-printed robot with seven degrees of freedom from shoulder to wrist and dimensions similar to an adult's right arm. With respect to prosthetic applications, its purpose is the study of reaching motion instead of grasping, as it comprises only minimal hand and finger features. Its motors are common off-the-shelf actuators (Robotis Dynamixel) and its skeleton presents a lightweight 3D-printed structure reducing the load supported by each motor. As a result, Reachy weighs only 1.4kg for 70cm length and remains notably cheaper than most commercially available robotic arms or prostheses. Its software is open-source and allows programming beginners as well as skilled roboticists to control the robot in Python.

Results: Through this interface, the robot can be connected to a wide variety of tools, from measuring devices to modeling and simulation software. As a proof of concept, we developed a basic application of endpoint control, featuring an inverse kinematics solver (IKPy) and a motion tracking system (Optitrack). IKPy was employed to compute Reachy's successive motor positions that would make its endpoint follow a 40cm-wide circle (1.26m circumference) in a frontal plane. Then, Reachy was put in motion to perform the whole movement in 3.5s, while the Optitrack device measured the actual endpoint position. Over 15 iterations of the movement, the mean position error with respect to the target path was 15.0±5.2mm, and the mean joint angle error was 0.922±0.780°. These results illustrate the typical accuracy that can be achieved with Reachy.

Conclusion: Reachy benefits from being an accessible and versatile platform. Its open-source software base and open-hardware structure make it an extensively connectable and customizable system. Among possible applications, Reachy can be controlled with various input sources such as electromyography or force-recording devices, allowing for the emulation of genuine prosthesis control techniques. Besides these biomechanical signals, Reachy can also be interfaced with vision-based systems, such as an eye-tracking device or camera coupled with image processing techniques.

O22.6 Sensory and motor parameter estimation for elbow myoelectric control with vibrotactile feedback

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BACKGROUND AND AIM: Despite technological advances in motorization of upper limb prosthesis, myoelectric control requires a long learning process leading to a high dropout rate among amputees. The absence of sensory feedback is very likely to impinge the appropriation of the prosthesis. Here, we explored a sensory substitution alternative with various configurations and settings for both vibrotactile feedback (Exp1) and myoelectric parameters (Exp2), as a preliminary step toward their future integration.

Methods: Exp1: Six vibrators were placed either on a line between the acromion and the lateral epicondyle or circumferentially around the arm. Space intervals between vibrators were either absolute (2cm) or proportional to the length or the circumference of the arm. Four dispositions were tested: longitudinal proportional (LP), longitudinal absolute (LA), circular proportional (CP) and circular absolute (CA). Three durations (60; 100 and 140ms) and three intensities (62.5; 100; and 167mA) were used for stimulations. Spatial discrimination test involved subjects to estimate location of the vibration, and perceived intensity was assessed by having subjects indicating the strength of the stimulation they experienced between 0 (no feeling) to 3 (strong). Exp2: EMGs from biceps and triceps were recorded during isometric contraction and used to control the elbow velocity of an avatar displayed on a screen. EMGs were filtered and normalized from maximal contraction. A threshold of minimum muscle activity and a gain of the velocity control were adjusted to allow fast an intuitive control.

Results: Exp1: The circular proportional (CP) disposition elicited better discrimination results than the 3 others dispositions ($p<0.05$). Duration, intensity and disposition were all found to influence the success rate scores (3 ways ANOVA $p<0.0001$). Stimulations with small duration (60ms) were perceived as being produced with a lower level of intensity. Longer and stronger stimulations elicited better score. Exp2: A threshold between 5 and 7.5% of the maximum force, and a velocity gain varying from 0.3 to 1.2 rad.s-1 for a change in muscle contraction of 10% MVC were found to enable precise control of the virtual avatar. Better performances were obtained with the velocity gain set at a higher value for triceps than for biceps.

Conclusions: Our results indicates that a circular proportional disposition of the vibrator around the arm is a well suited configuration for sensory substitution. Moreover, they provided valuable information on stimulation time and intensity for vibrators, as well as on threshold and gain of the elbow myoelectric control. Our next step will be to combine sensory feedback given by vibrator around the arm (CP) to the myoelectric control of the avatar, on healthy subjects and amputees. This sensory substitution have great potential to improve prosthesis control, acceptance, and could also attenuate phantom limb pain.

O23 MOTOR CONTROL IV

O23.1 Do neural modulations contribute to force enhancement during and after the stretch-shortening cycle?

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BACKGROUND AND AIM: The stretch-shortening cycle (SSC) is a combination of a lengthening (stretch) contraction immediately followed by a shortening contraction. Recently, it has been shown that the mechanisms of residual force enhancement (RFE) likely contribute to the enhanced work and power production during the shortening phase of the SSC. However, to date it remains unclear if the RFE-related increase in performance is purely mechanical in nature. Thus, the purpose of this study was to examine neural modulations during and after lengthening, shortening, and SSC contractions.

METHODS: Plantar flexion torque (200Hz) and EMG Data (5000Hz) of m. triceps surae were recorded during and after lengthening, shortening, SSC, and isometric contractions (n=11 subjects). Contractions were evoked by percutaneous stimulation of the posterior tibial nerve (6s duration, 20Hz pulse frequency, 1ms pulse width). Stimulation intensity was set so that each stimulation evoked a M-wave and a H-reflex response in soleus muscle. The torque produced by this stimulation resulted in 45±11% of maximum voluntary isometric torque. Dynamic contractions were performed over an amplitude of 15°, from 10° plantar flexion to 5° dorsiflexion (ω=60°s-1, α=50°s-2). M-waves and H-reflexes were determined via peak-to-peak amplitude and normalized to a contraction specific maximum M-wave (Mmax). M-waves, H-reflexes, angular impulse during shortening, and isometric steady state torque after displacement were compared between contraction conditions, either by Student´s T-Test or repeated measures ANOVA (α≤.05).

RESULTS: Angular impulse was increased during the concentric phase of the SSC compared to pure shortening (p=.017). RFE of 12.1±5.5% was observed after pure lengthening contractions (p=.001) and RFD of 19.6±5.8% was observed after pure shortening contractions (p=.000). After SSC, RFD was reduced to 10.7±4.6% (p=.000). M-wave and H-reflex remained stable over all contractions during dynamic conditions (p=.297). H-reflex after lengthening contractions (24.8±18.3%Mmax) was increased (p=.007) compared to pure isometric contractions (20.7±19.1%Mmax). Although H-reflex after SSC (24.0±17.9%Mmax) equaled that after pure lengthening contractions, there was no difference (p=.15) to H-reflexes after pure shortening (20.9±19.1% Mmax) and pure isometric contractions (21.3±19.5% Mmax).

CONCLUSIONS: The increased H-reflex after pure lengthening contractions demonstrated an increased Ia-excitability when RFE was present. This suggests that neural modulations might contribute to RFE. Regarding SCC, the reduced RFD indicates that RFE counteracts force depression after SSC. However, since the increase in H-reflex after SSC showed no significance, potential contributions of neural modulations remain to be determined.

O23.2 Agonist and antagonist activation during dynamic functional tasks in a synergistic muscle pair

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Delsys and Altec Inc

BACKGROUND AND AIM: Studies of motor unit firing behavior have reported varying degrees of common drive, or correlated firing rates, depending on whether muscles are activated in synergist or antagonist contractions [1]. However, these reports are limited to the study of isometric contractions. There remains a need to determine how the central nervous systems regulates functional tasks of normal voluntary movement.

Methods: We employed a recently developed surface electromyographic (sEMG) decomposition technology to investigate the activation of motor units during cyclic movements of the upper-limb. sEMG signals were recorded from the extensor digitorum and flexor digitorum profundus muscles during voluntary dynamic activities of opening/closing the hand and object grasping. The recorded sEMG signals were processed by the algorithms to extract the action potentials and corresponding firing times of the active motor units [2]. The measured motor unit data were validated for accuracy and compared with the force, position and angular velocity of the fingers, hand and arm using the Trigno sensor system (Delsys, Inc. Natick, MA).

Results: We observed that motor unit firing rates within each muscle: 1) were ordered in an inverse hierarchical relationship relative to the motor unit action potential amplitude as previously described by the onion-skin phenomenon [3]; and 2) were correlated with respect one-another and with the output movement in accordance with the common drive property [1]. The firing rates of motor units from different muscles maintained a high degree of correlation across all activities, but showed variable latency. When the muscles were activated as synergists during object grasping, motor unit firing rates were correlated at approximately zero latency. When the muscles were activated as antagonists during opening/closing of the hand, the latency of the correlation increased.

Conclusions: These data indicate that the central nervous system coordinates the synergist and antagonist activation of muscles by regulating the latency of the common drive between the motor unit firing rates during different voluntary movements.

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O23.3 The Neuromuscular Mechanisms and Motor Learning Adaptations Contributing to Cross Education in the Upper and Lower Limbs

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BACKGROUND AND AIM: Cross education is the strength gain transferred to the homologous, contralateral limb following unilateral training. Similarly, intermanual transfer is the cross body transfer of skill performance following motor practice. Although widely studied, these phenomena are rarely examined concurrently. Further, neural adaptations such as a change in motor unit firing rates have remained equivocal in the literature. The present study examined neural adaptations in the contralateral limb following unilateral resistance training, and evaluated the contribution of motor learning to cross education.

Methods: Forty participants (20M, 20F) were randomly assigned to complete a 6-week unilateral training program for either dominant limb wrist flexion or dorsiflexion. Training consisted of dynamic exercises performed 4x/week at 80% maximal force. Testing was performed twice pre-training, post-training, and following 6-weeks of detraining (retention). Each session examined all four limbs (trained, contralateral, untrained dominant, untrained non-dominant). Maximal voluntary contractions with twitch interpolation were performed to evaluate strength, muscle activity, and central drive. Trapezoidal isometric contractions to 60% maximal force were performed to evaluate motor unit firing rates and force variability. Analyses of covariance were performed for the upper and lower limbs separately, comparing the experimental limb (trained or contralateral) to the homologous control (dominant or non-dominant) of the alternate group at each session.

Results: There were no significant differences between sexes. Contralateral limb strength was greater than the control arm ($p=0.21$) and leg ($p=0.10$) at post-training, following strength increases of 11% (arm) and 15% (leg). Furthermore, contralateral limb strength was greater than the control arm ($p<0.01$) and leg ($p=0.06$) at retention following continued strength increases for a total cross education of 18% (arm) and 22% (leg). At post-training, the contralateral limb demonstrated increases in agonist RMS amplitude in the arm (6%, $d=0.16$) and leg (15%, $d=0.43$), V-wave amplitude in the leg (41%, $d=0.59$), and central activation ratio in the arm (1.2%, $d=0.52$). The force variability indicated the presence of motor learning in the contralateral limb.

Conclusions: Neuromuscular mechanisms mirrored force increases at post-training and retention testing substantiating the adaptations in central drive associated with cross education. However, no change in motor unit firing rates of the trained or contralateral limbs was observed. The continued strength increase at retention identified the presence of motor learning in cross education, which was confirmed by the force variability results. The amount of cross body transfer (contralateral/ipsilateral gain) was greater in the leg than arm at post-training indicating preferential transfer in the lower limb.

O23.4 Neuromechanical coupling within the triceps surae muscle group and its consequence on force sharing

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Many different muscle coordination strategies are theoretically possible to achieve the same motor goal, as there are more synergist muscles acting upon a joint than degrees of freedom. Little is known about the factors that influence the coordination of synergist muscles that act across the same joint. The aim of this study was to determine the nature of the relationship between the ratio of activation measured during a submaximal plantarflexion task and the ratio of force-generating capacity between the three heads of the triceps surae (gastrocnemius medialis [GM], gastrocnemius lateralis [GL] and soleus [SOL]).

This study was conducted with 20 healthy volunteers. Participants attended a two experimental sessions (in order to test-retest reliability of the activation strategies) during which they performed a series of maximal and submaximal isometric plantarflexion tasks. Muscle physiological cross-sectional area (PCSA) was estimated using B-mode ultrasound (fascicle length) and magnetic resonance imaging (volume) and was considered as an index of muscle-force generating capacity. The activation of GM, GL and SOL was estimated using surface electromyography (EMG). The magnitude of both muscle activation and muscle PCSA varied greatly between participants. During the submaximal contraction performed at 20% of MVC, the mean ratio of GM/GL and SOL/TS EMG amplitude was 65.0 ± 13.2% and 44.8 ± 8.9%, respectively. The mean ratio of GM/GL and SOL/TS PCSA was 68.6 ± 4.6% and 61.6 ± 5.4%, respectively. Although there was no significant correlation between the distribution of activation and the distribution of PCSA between mono- and bi-articular muscles (SOL/TS ratio), a positive correlation was found when considering the two bi-articular muscles that share the same function (GM/GL ratio). Specifically, the greater the PCSA of GM compared with GL, the stronger bias of activation to the GM. As a consequence, an imbalance of force between the three heads of the triceps surae was observed, the magnitude of which varied greatly between participants.

These results provide insight into our understanding of the interplay between the activation a muscle receives and its torque generating capacity. These results may also have clinical relevance as they provide the necessary first step to consider individual muscle coordination strategies as an intrinsic risk factor to the development of Achilles tendinopathy.

S13 SYMPOSIUM: INSIGHTS INTO COGNITIVE PROCESSES FROM MOTOR SYSTEM MEASUREMENTS

S13.1 Active braking of whole-arm reaching movements provides single-trial neuromuscular measures of movement cancellation

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BACKGROUND AND AIM: Movement inhibition is an aspect of executive control that can be studied using the countermanding paradigm, wherein subjects try to cancel an impending movement following presentation of a stop-signal. This paradigm permits estimation of the stop-signal reaction time (SSRT), or the time needed to respond to the stop signal. Many countermanding studies have examined fast, ballistic movements like saccades, even though many movements in daily life are not ballistic, and can be stopped at any point during their trajectory. A benefit of studying the control of non-ballistic movements is that antagonist muscle recruitment, which serves to actively brake a movement, presumably arises in response to the stop signal.

Methods: Here, nine human participants (2 female) performed a center-out whole-arm reaching task with a countermanding component, while we recorded the activity of upper-limb muscles contributing to movement generation and braking.

Results: The data show a clear response on antagonist muscles to a stop signal, even for movements that have barely begun. As predicted, the timing of such antagonist recruitment relative to the stop signal co-varied with conventional estimates of the stop-signal reaction time, both within and across subjects. The timing of antagonist muscle recruitment also attested to a rapid reprioritization of movement inhibition, with antagonist latencies decreasing across sequences consisting of repeated stop trials; such reprioritization also scaled with error magnitude.

Conclusions: We conclude that antagonist muscle recruitment arises as a manifestation of a stopping process, providing a novel, accessible, and within-trial measure of the SSRT.

S13.2 Intensified motor activity makes for faster responses when deciding under speed pressure

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Great strides have been made towards identifying and understanding key principles of brain function through the study of perceptual decision-making. One of the key findings has been that neural populations in non-human primates reflect the unfolding decision process. Newly developed approaches in electroencephalography (EEG) and electromyography (EMG) have now made it possible to trace decision formation in a similar manner non-invasively in humans. Here, we present data supporting the hypothesis that motor activity read-out in cortical motor preparation as well as muscle activation is modified by cognitive processes. When decision makers prioritize speed over accuracy, neural activity is elevated in brain circuits involved in preparing actions. Such urgency signal components, defined by their independence from sensory evidence, are observed even before evidence is presented and can grow dynamically during decision formation. Using motion and contrast discrimination tasks, we show that dynamic urgency impacting cortical action-preparation signals is echoed downstream in electromyographic indices of muscle activation, but does not directly influence upstream cortical levels. A motor-independent representation of cumulative evidence reached lower pre-response levels under conditions of greater motor-level urgency, paralleling a decline in choice accuracy. We further show that those effects are amplified if speed pressure is upheld over a block of consecutive trials.

S13.3 Reaction time fractionning with EMG: what can muscles tell us about mental processes

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BACKGROUND AND AIM: Cognitive psychologists/neuroscientists aim at inferring the mental processes at play during the realization of a task, based on fine analysis of performance sensitivity to experimental manipulations. However, overt performance might be under-constraint and additional neurophysiological measures might be useful for such endeavor. Although many neurophysiological measures are nowadays available, EMG, with its unbeatable signal/noise ratio compared to other techniques usable in Humans, has provided essential information in the last 10 years. I will review the main results gathered so far.

Methods: In reaction time (RT) task, where response are given by thumb isometric key presses, activities of the flexor policis brevis are recorded. Based on the onset of EMG activity, the whole RT can then be fractionated into two sub-intervals: from stimulus onset to EMG onset (termed pre-motor time'', PMT) and from EMG onset to mechanical (behavioral) response (Motor Time'', MT). Besides those chronometric indices, the shape of the EMG burst are analyzed. The effect of various cognitive manipulations (priming, stimulus-response compatibility, speed-accuracy trade-off etc...) or groups (e.g. Parkinson's disease patients, children etc...), on RT can then be traced to be located on PMT and/or MT. The information gathered from the fractionation can also be used to add constraints to formal decision-making models.

Results: I will first review several published studies using this methodology to assess the locus of different cognitive manipulations. Consistently, some factors were shown to spare the MT, while some other clearly affected it, sometimes even selectively. In some cases, this methodology allowed to resolve some long-lasting debates in the literature (for example motor priming) or clarify some ambiguities in the literature. I will then present more recent data showing how this methodology allowed us to investigate the psychological/neurophysiological validity of formal model of decision making.

Conclusions: Although many neurophysiological techniques are now available for cognitive psychologists/neuroscientists, their limited signal/noise ratios prevent analysis at the single trial level, hence hindering essential information. In contrast, EMG is measurable on each individual trials, and, although it may appear to be far from the cognitive processes, it provides a powerful windows of the cognitive processes just preceding the motor execution and allows to assess to what extend decision and motor execution are (in)dependent.

O24 EMG MODELING & PROCESSING III - SIGNAL ANALYSIS

O24.1 Application of a genetic algorithm to establish baseline data for an SEMG noise detection algorithm

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University of New Brunswick

BACKGROUND AND AIM: The Pairwise Attribute Noise Detection Algorithm (PANDA) has been recommended by others as a way to classify surface electromyography (SEMG) signals as clean or noisy. PANDA assigns a 'Noise Factor' to a suspect test signal by comparing the features of the test signal to the features of a baseline data set. This 'Noise Factor' can then be used to flag the test signal as clean or noisy. The baseline data set can be constructed using an initial set of in vivo recorded signals (records) which can be used by PANDA to flag all further records. While this approach guarantees a realistic baseline dataset, the records may be contaminated with noise and thus may affect PANDA's performance. Simulated signals can instead be used as they are guaranteed to be clean, but they may not be realistic. This work investigated a method to combine the two approaches by using a genetic algorithm (GA) to produce realistic clean simulated signals obtained by 'matching' records.

METHODS: A simulator developed at the University of New Brunswick, called "Myosim" was used to generate the simulated signals. A GA was employed to optimise the generative parameters of the simulator, such as the number of active motor units, number of fibres, depth of the fibres, etc. to produce clean signals that had a power spectrum similar to that of a particular record. Noise prone regions in the spectrum was excluded in the matching process. SEMG records from 11 participants at two different MVC values (15 % and 25 %) were matched. The generative parameters corresponding to each record was found using the GA, which were then used to construct the baseline data set. A k-fold cross-validation was then used to assess the performance of the algorithm by removing the simulated data corresponding to a particular record from the baseline data set and then testing that record with the rest of the baseline data set in action. This process was repeated for all the records and the average number of segments flagged as noisy was recorded as the false positive rate (i.e. classifying clean signals as noisy). The process was then repeated by contaminating the test records with different kinds of noise at different SNR values to evaluate PANDAs ability to detect noisy signals.

RESULTS: The false positive rate was obtained to be 20% for a specific threshold. For noisy test segments, PANDA was able to detect all signals contaminated with Motion Artefact (MA) having SNR≤3 dB, with Powerline Interference (PLI) or MA+PLI having SNR ≤5 dB and amplifier saturation ≥3 %.

CONCLUSION: PANDA was able to identify noisy SEMG records using the simulated baseline data set obtained from matching records using a GA. Additional research needs to be done to explore optimal setting for PANDA flagging criteria and GA configuration.

O24.2 Numerical Identification of Motor Units using an Optimal Control Approach

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BACKGROUND AND AIM: While significant advancements have been made in identifying the activity of individual motor units from the surface EMG signal through EMG decomposition methods, a reliable and accurate method to determine the position of the motor units from the sEMG signal is not yet available. Previous works consider spatial data only or use simple parametric models within a least squares approach. Thus we derive an approach to automate the identification of motor units using techniques from numerical simulation and non-linear optimization.

Methods: We use the adjoint equation of the electrostatic poisson-equation to derive a mathematical model, which allows to efficiently simulate sEMG measurement. With this model we can state an optimal control problem to identify the position of motor units from sEMG measurements. To solve the problem numerical, we first discretize the problem with the finite element method and solve it then with an SQP-method.

Results: For a test problem our optimization method converges in a few iterations and yields accurate results.

Conclusions: Our algorithm is capable of identifying the location of motor units from out measurements in a test setting. Our next step is its application to real measurement data to assess the accuracy of our forward model and the influence of modeling errors and noisy data on the identified solution.

O24.3 Relationship Between Indwelling Motor Unit Activity and Surface Electromyographic Variables Between 20 And 100 Percent Of Maximal Voluntary Contraction

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BACKGROUND AND AIM: The relationship between motor unit (MU) activity and surface electromyography (sEMG) has been problematic due to difficulties obtaining experimental data. Therefore, this study evaluated the relationship between intramuscularly recorded MU behavior and sEMG in voluntary contractions from 20 to 100% of maximal force.

Methods: Forty-eight college-aged individuals (F24; M24) participated in the study. Participants sat in a testing chair designed to isolate the dorsiflexors during isometric contractions. Force was measured from a load cell (JR3 Inc., Woodland, CA) beneath the footplate. Submaximal contractions were completed in balanced order, while maximal voluntary contractions were completed prior to and after the submaximal portion. Contractions were 8-sec, separated by 3-min rest. The sEMG was recorded from monopolar Ag/AgCl electrodes (Grass F-E9, Astro-Med Inc., West Warwick, RI) placed on an electrically identified tibialis anterior motor point. An intramuscular quadrifilar electrode (Viasys Healthcare UK; Surrey, England) was inserted distal to the surface electrode. Muscle electrical activity was band-pass filtered and amplified (Grass P511; Astro-Med Inc., West Warwick, RI) prior to sampling at 25.6 kHz (DASYLab; DASYTEC National Instruments, Amherst, NH). Surface and intramuscular EMG signals were reduced in Matlab (The Mathworks Inc.; Natick, MA). Motor unit action potentials were identified using EMGlab (www.emglab.net). The following measures were calculated from a 2-sec window at the most stable portion (± 2.5%) of the contraction: (1) mean motor unit discharge rate (MUDR); (2) number of detected motor units (nMU); (3) mean power frequency (MPF); (4) root-mean-square (RMS) amplitude; (5) mean spike frequency (MSF); and (6) and mean spike amplitude (MSA). Data were analyzed using a repeated measures correlation technique (Bakdash & Marusich, 2017).

Results: Force levels (20-100%) were highly correlated with MUDR ($r=0.88$, $p<0.01$) and nMU ($r=0.83$, $p<0.01$). Mean power frequency had low but significant correlations with MUDR ($r=0.23$, $p<0.01$) and nMU ($r=0.24$, $p<0.01$). Mean spike frequency showed no relationship with either MUDR ($r=0.10$, $p>0.01$) or nMU ($r=0.08$, $p>0.01$). Amplitude variables were highly correlated to MU activity. Both RMS and MSA had identical correlations ($r=0.86$, p's<0.01) with MUDR across force levels. Correlations with nMU were also very good for RMS and MSA ($r=0.74$, $p<0.01$; $r=0.77$, $p<0.01$, respectively).

Conclusions: The sEMG amplitude was highly sensitive to changes in MUDR and nMU, but the frequency measures were not. In the case of the frequency measures, exactly 50% had moderate positive correlations, while the other 50% had moderate negative correlations, with the exception of MSF ($r=0.17$, $p>0.01$), the correlations range between 0.41 and 0.58 ($p<0.01$). The result was an overall low relationship with MU activity when combined, which could explain previous discrepant experimental findings.

O24.4 An algorithm to identify and quantify intermittent (burst-like) muscular patterns of activity in HD-sEMG signals

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Intermittent (burst-like) sEMG activity has been observed in the gastrocnemius muscle during quiet standing [1] and on the erector spinae of sitting violin players. An algorithm based on HD-sEMG detected with 16x8 electrode grid (i.e.d.=10mm, ø=3mm) placed on the erector spinae of a violinist was developed for automatic counting of the bursts. A total of 128 monopolar signals were acquired on each side of the spine at 2048 samples/s and the longitudinal differential signals were computed to reduce power-line and ECG common mode interferences. A moving average window of 60 samples (30ms), with 30 samples overlapping, was applied to the square of the signal to obtain its envelope sampled at 66 samples/s which is 2.5 Nyquist rate. The envelopes were then added along each column of the grid and a threshold of 5% of the peak value of the sum was applied. The resulting binary signal identifies the frequency and duration of the bursts found on the multichannel grid that are greater than noise. The algorithm automatically a) neglects isolated sEMG spikes that are shorter than 20ms or are present on less than 3 channels of a column of the grid, and b) merges two bursts that are separated by less than 65ms. The algorithm was applied to three recordings of 20s duration each, and results were compared with two known methodologies and with the evaluations of 13 human observers. The two methodologies were: 1) Lowpass filtering (5th order bidirectional Butterworth, 5Hz cutoff) of the rectified signal with a threshold based on the background noise to compare and identify patterns of activity greater than noise; 2) Hilbert transform of the raw signal (window size of 30ms) to obtain the analytic signal to extract the envelope with a threshold based on the noise during relaxed conditions [2].

Table 1. Comparison of bursts detection methods and count of burst-like activity compared to 13 human observers. Three recordings from three subjects. Observation time =20 s

Method	**N. of bursts found**	**Human counting (N=13 operators, mean ± st.dev, range)**
1. 5th order Butterworth Low-pass filtering, 5Hz cutoff, of rectified EMG and threshold of $4\square V_{RMS}$.	Sig. a: 28 Sig. b: 30 Sig. c: 30	Sig. a: 51.7±4.2, 44-59
2. Hilbert transform, window size of 60ms [2], threshold of $4\square V_{RMS}$.	Sig. a: 73 Sig. b: 95 Sig. c: 84	Sig. b: 52.1±7.4, 47-68
3. Proposed algorithm. Moving average windows of 60 samples (30 ms) with 30 samples overlap on the squared signal with threshold of 5% of the peak value.	Sig. a: 48 Sig. b: 49 Sig. c: 55	Sig. c: 57.0±4.3, 46-59

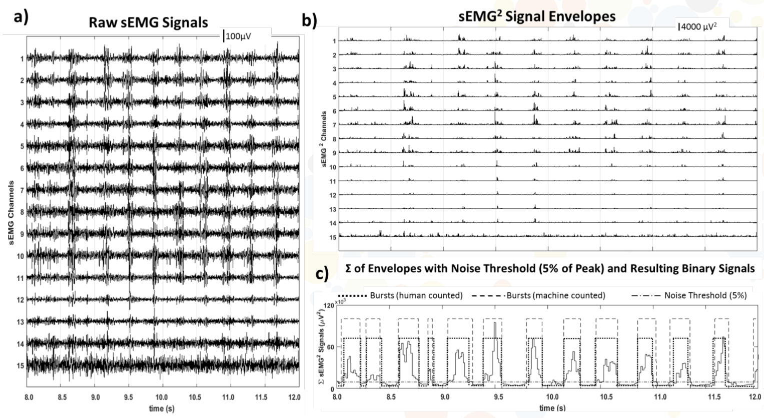

Figure 1. a) Differential signals from one column of a 16x8 HDsEMG grid applied to the erector spinae muscle of a violinist during playing; b) Bursts are estimated with the algorithm described in the text; c)Sum of envelopes with noise threshold as 5% of the peak value and resulting binary signals.

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O25 WEARABLE SENSORS & ACCELEROMETRY

O25.1 Estimating dynamic loading during walking using low-cost ankle accelerometers in postmenopausal women

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BACKGROUND AND AIM: Physical activity (PA) interventions are a common target for reducing fracture risk in postmenopausal women with low bone mineral density (BMD) [1]. Although accurate tracking of PA in free-living environments is improving, the ability to translate this activity into evaluations of bone health is currently limited. We previously demonstrated that low-cost wearable accelerometers can be used to estimate vertical ground reaction forces (GRFs) in young adults, with greatest success at the ankle [2]. This study aim was to validate the use of ankle-worn accelerometers to estimate the vertical GRFs responsible for bone and joint loading in postmenopausal women during gait at a range of self-selected walking speeds.

Methods: Seventy women, at least one year postmenopause, aged 61±7 years, completed a minimum of five walking trials, while wearing bilateral ankle Actigraph GT3X+ accelerometers (100 Hz), at each of three self-selected walking speeds corresponding to slow, normal and fast gait along a 30 m walkway instrumented with five force plates (three AMTI, two Kistler) and with photocells at either end to estimate walking speed. Body weight normalized GRFs (GRFbw) were collected at 600 Hz and force-plate foot-falls were verified using 2D continuous video data recorded simultaneously at 60 Hz. Peak vertical ankle accelerations (pVacc) and associated GRFbw were collected for each complete foot-fall during data analysis. Linear mixed models were employed to characterize differences in self-selected walking speed, pVacc and GRFbw among walking speed categories. Linear regression analysis was performed to estimate the relationship between pVacc and GRFbw.

Results: Mean (SD) self-selected slow (1.08±0.19 m/s), normal (1.39±0.21 m/s) and fast (1.66±0.26 m/s) walking speeds were significantly different, resulting in a distribution of GRFbw and pVacc which characterized this population. Regression analysis found a linear correlation of r=0.70 (95%CI[0.64 - 0.76] via 2500 bootstrap passes) between pVacc and GRFbw (Fig. 1). Five-fold cross-validation yielded an average mean-absolute-error (MAE±SD) rate of 6.8±5.4% between predicted and actual observations of GRFbw, and a root-mean-square-error (RMSE) of 0.087 BW, suggesting strong model agreement.

Conclusions: This study is the first to show a strong relationship between low-cost ankle accelerometry data and high fidelity lower-limb loading approximations in postmenopausal women. This relationship provides us with the information necessary to estimate real-world limb and joint loading for the purposes of accurate PA tracking and improved individualization of clinical interventions.

ACKNOWLEDGEMENTS: Funding was provided by the National Institutes of Health (R21 AR066643). Stacy Loushin performed subject recruitment and data collection. REFERENCES: 1. Howe, TE et al. (2011) Cochrane Database Syst Rev. (7):CD000333 2. Fortune, E et al. (2014) J Appl Biomech. 30(5):668-74

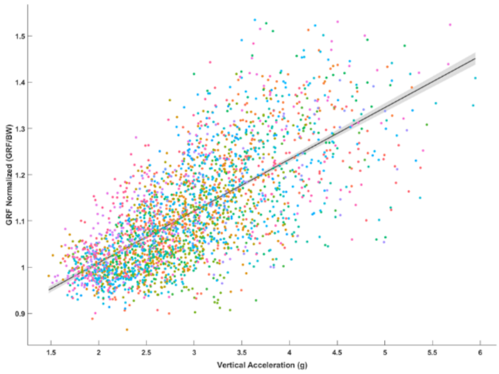

Figure 1: Peak vertical acceleration (pVacc) vs normalized ground reaction forces (GRFbw) for each subject, differentiated by color. Linear regression line with confidence intervals provided for reference.

O25.2 Quantification of movement performance in the upper extremities of children with obstetrical brachial plexus palsy (OBPP) using accelerometers

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BACKGROUND AND AIM: Many musculoskeletal and neurological disorders reduce patients' quality of life. Minimally obtrusive wearable sensors e.g. accelerometers have been used to gather kinematic data from human movement. This study's goal was the development of a quantification method for the detection and classification of movement quality in children with obstetrical brachial plexus palsy (OBPP).

METHOD: Twenty OBPP patients (13.9 ± 6.7 yrs.) and 10 healthy subjects (27.8 ± 2.1 yrs.) were recruited. The Modified Mallet Scale (MMS) was used to classify the functionality and appearance of patients' arms. Three movement tasks were selected which simulated difficult daily tasks for the patients: Hand to Mouth (HM), Hand to Neck (HN), and Hand to Back (HB). During measurements each movement task was repeated twelve times. A total of 5 triaxial, digital accelerometers were located on an individual's chest and distally on their forearms and upper arms. For each body segment, acceleration signals were recorded in each sensor's 3 Cartesian axes. The Cartesian coordinates were next converted into spherical coordinates. Three accepted mathematical parameters: subtraction of the maximal amplitudes (Amp_sub), cross-correlation coefficient (CC_coef), and area outside (A_out) of the standard deviation (SD) were implemented to quantify the differences in movement between the healthy and pathological sides of the body. A data set of 54 features was generated for each task based on combinations of 6 coordinate axes per accelerometer, 3 body segments and 3 parameters. Further analysis involved the development of a decision tree to determine scores and finally classification to the MMS. Firstly, the linear regression line relating the feature values to the MMS classes was determined. Next, the gradient and the coefficient of determination, R^2 were used to implement a hierarchical threshold-based decision tree in which selection criteria dictated feature extraction. Subsequent weighting and summation of the features produced a final score to enable classification of patients' movement.

Results: The selected movement tests evaluated the entire range of movements in the upper limbs. The accelerometer-based measurement system captured all the patients' movements. A maximum of 6 features was selected for each movement based on the decision tree. Classification into five classes on the basis of the score resulted in a 70 - 80% agreement with the patients' MMS assignment depending on the movement task performed. For each movement task distinction between MMS I and II proved to be difficult. This is based on the fact that these patients were unable to completely perform the tasks to the end-point.

Conclusion: Accelerometers offer a suitable option for the evaluation and quantification of movement patterns during various daily activities. Such accurate and readily adaptable technology fosters the use of automatic scoring systems in clinical and non-clinical environments.

O25.3 Comparison of features extracted from data simultaneously recorded using different commercially available wearable accelerometers and a force plate.

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BACKGROUND AND AIMS: Wearable sensors containing accelerometers allow precise assessment of human movement, facilitating quantitative comparison between assessments. A variety of commercially-available wearable sensors exist, with varying technical specifications, physical dimensions, and composed of different materials. Recommended sensor attachment locations and methods vary according to manufacturer. Researchers choose accelerometers based on these differences, however the choice is not always clear. Additionally, algorithm results may not be independent of accelerometer type. While each sensor technology has been validated against criterion movement analysis tools, little research exists quantitatively comparing data collected using different sensor brands. Here, four wearable sensors are compared to force plate data during a commonly used movement and falls risk assessment, the five times sit to stand test (FTSS).

METHOD: Tri-axial accelerometer data were collected, as three healthy participants (2 M; mean(SD) age=28(7) years; BMI=25(1) kg/m2) wore four wearable sensors (S1-S4; ±2g) on the sacrum, simultaneously with force plate (200Hz; Bertec) data as the criterion during three FTSS trials; S1: Shimmer3 (102.4Hz), S2: Delsys Trigno (148.1Hz), S3: MC10 BiostampRC (125Hz) and S4: APDM Opal (128Hz). For one subject, data for S2 were not available. Sensors were stacked in pairs, with their axes aligned, and adhered to the skin and to each other to minimise movement between sensors. A stopwatch was used to record FTSS total time, the standard clinical measure. Data were analysed in Matlab. All vertical acceleration data were filtered using a 4th order low-pass butterworth filter with 5Hz cutoff frequency. For each sensor, sit-stand-sit (SSS) movements were detected using a peak detection based algorithm to compute total time and SSS times (Fig. 1). Absolute error in total time and mean SSS time relative to force plate values were compared for all sensor and stopwatch data. Spectral edge frequency (95% power; SEF) was also computed for each SSS, and compared between sensors.

Results: Mean total time computed using force plate values was 9.89(0.73) s. Error in total time relative to force plate values was 0.41(0.46) s for stopwatch data, 0.27(0.29) s for S1, 0.34(0.17) s for S2, 0.37(0.24) s for S3 and 0.43(0.43) s for S4. SSS time error, (S1: 0.05(0.06) s; S2: 0.07(0.03) s; S3: 0.07(0.05) s; S4: 0.09(0.09) s) and SEF (S1: 3.29(0.79) Hz; S2: 3.03(0.78) Hz; S3: 3.30(0.77) Hz; S4: 3.32(0.81) Hz) were comparable for each sensor.

Conclusions: Initial results suggest all sensors have comparable performance relative to force plate and stopwatch data for the examined FTSS timing and frequency features, based on the implemented algorithms. Data collection and analysis across a larger population are ongoing, which will allow further investigation of these findings, including angular velocity data and additional clinical gait and balance tests.

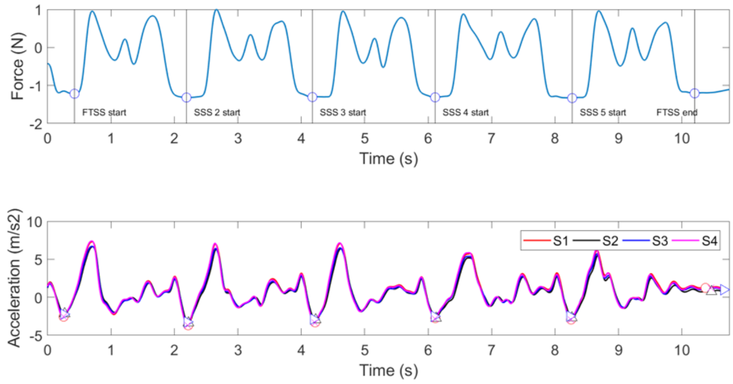

Fig. 1. Example of force plate (top) and accelerometer (bottom) data simultaneously recorded during an FTSS test. Markers are presented illustrating the detected start of each sit-stand-sit (SSS) movement. Vertical lines illustrating the start and end of the FTSS test, and the start of each SSS are also presented for force data. For this example, the stopwatch-measured total time was 9.92 s, while total time calculated using force plate data was 9.78 s.

O25.4 A comparative analysis of different sensor fusion algorithms for orientation estimation using magnetic and inertial sensing

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BACKGROUND AND AIM: Magneto-inertial sensing technology has great potential for providing real-time estimation of human joint kinematics. In general, the orientation of magneto-inertial measurement units (MIMUs) can be obtained by fusing the data recorded by a triaxial gyroscope, accelerometer and magnetometer. Although several filters for the determination of the MIMU orientation have been proposed, consensus about the best algorithms available and their accuracy levels is still missing. The purpose of this study is to compare, through a set of benchmarks, the performances of 4 sensor fusion algorithms for MIMU orientation in terms of self-consistency and accuracy.

Methods: two complementary filters (MAD1 and VAL2) and two extended Kalman filter (EKF3, XKF4) were selected and implemented (MATLAB). Test description - Four MIMUs (Xsens, MTW, fs=100 Hz) were aligned and attached to a wooden board. For each algorithm, inter-MIMU consistency was evaluated by computing the standard deviation (SD) of the orientation of the 4 MIMUs in static conditions (test 1) and while an operator was rotating at low and high speed the board of about 360° around each of its axes at a time (test 2). For test 3a, we attached a MIMU on a moving wooden rod connected to a stationary frame by a perfect hinge joint. Data were recorded while an operator was rotating the rod 3 times about the axis of rotation at different speeds. The variability in the estimate of the direction of the fixed rotation axis was computed for each algorithm in terms of SD. The same experimental set-up was used to assess methods accuracy during rapid inversions of the angular velocity and mechanical shocks (test 3b and 4). For this data set, we used as reference the orientation provided by XKF (internal fs=1800 Hz).

Results: inter-MIMU consistency results are listed in Table 1. Despite MIMUs had the same alignment, each algorithm exhibited inter-MIMU consistency different from zero during test 1 and 2. During test 3b and 4, the largest errors were found during the peaks of angular and linear accelerations.
Conclusions: In general, MAD showed the worst performances both in terms of self-consistency (test 2) and accuracy (tests 3a, 3b and 4), while VAL and EKF exhibited similar performances. Differences between the orientation estimates provided by XKF and those computed using MAD, VAL and EKF could be due to the lowest values of the fs (1800 Hz vs 100 Hz). Low computational-cost is the main advantages of VAL (complementary filters) while EKF is more flexible and allows to implement specific state-augmentation techniques to compensate sensor bias and magnetic disturbances. Future work will be devoted to further investigate the performance of different algorithms under conditions like those occurred in clinical movement analysis. 1: Madgwick, 2010 2: Valenti et al., SENSORS, 2015 3: Sabatini, SENSORS, 2011 4: Xsens

Test	EKF	XKF	MAD	VAL
1 (SD)	1.7°	0.7°	1.9°	3.1°
2 - slow (SD)	2.1°	1.4°	3.7°	2.8°
2 - fast (SD)	2.5°	1.5°	11.6°	8.3°
3a (SD)	1.6°	1.6°	3.4°	1.8°
3b (Max deviation from XKF)	4.1°	-	5.5°	1°
4 (Max deviation from XKF)	2.8°	-	12.5°	3.3°

Table 1: results of inter-MIMU consistency (1 and 2) and accuracy (3,4 and 5) tests.

O26 KNEE BIOMECHANICS AND REHABILITATION III

O26.1 Motor Unit Characteristics of Vastus Medialis Muscle in ACL Reconstructed Knees After Second ACL Tear

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BACKGROUND AND AIM: Repeated rupture of the anterior cruciate ligament (ACL) is a fundamental complication after primary ACL reconstruction. Amongst others, risk factors of the neuromuscular system cannot be excluded. The objective of this study was to compare different characteristics of identified motor units of the vastus medialis muscle with those of the uninjured contralateral side.

Methods: Eleven male athletes (age: 27 (SD 7) years, Tegner activity level: 7 (1)) were examined at the ruptured (R) and uninjured (C) sides before the revision surgery. The amount of anterior translation (AT) of the tibia was quantified using the KT-1000 (MEDmetric, San Diego, USA) arthrometer device. After determining maximum voluntary torque (MVT) of knee extension, patients underwent isometric contraction at 80% MVT for a maximum of 33 seconds. Activity of vastus medialis muscle was recorded with a surface array (Delsys, sampling rate: 20 kHz). The signals, from which the mean frequency (MF) of the power spectral density was estimated, were decomposed into individual action potentials of motor units (MU) using automated algorithms (EMGworks). The mean firing rates (FR) of the identified MU were related to the corresponding recruitment thresholds (RT) of the MU (goodness of fit, r square; regression slope) separately for each patient and side, respectively. Additionally, vastus medialis muscle biopsies were obtained at the end of the ACL revision surgery from R only. For fiber type differentiation, histochemical staining was performed on frozen sections. Also, linear regression analyses were applied to examine the relationships between proportions of muscle fiber distributions (for R only) and MVT, MF as well as the MU r squares.

Results: The MVT values at the injured side were on average lower (R: 281 (87) Nm; C: 315 (69) Nm; P = 0.09; d = -0.6). In contrast, MF (R: 85 (18) Hz; C: 88 (16) Hz; P = 0.5; d = -0.2), MU r squares (R: 0.57 (0.19); C: 0.60 (0.34); P = 0.8; d = -0.1) and MU slopes (R: -0.09 (0.04); C: -0.11 (0.07); P = 0.3; d = 0.3) did not differ between sides. The amount of injured knees' AT was positively associated with the MVT differences (r = 0.54, P = 0.08). The MVT values were negatively associated with the proportion of type I fiber area and explained 58% of the variance (R: r = -0.76, P = 0.01). The MF also correlated with the MVT values, but for the uninjured side only (R: r = -0.19, P = 0.6; C: r = -0.53, P = 0.09). The proportion of type I fiber area was negatively related to the r square of fit of the identified MU (R: r = -0.60, P = 0.05).

Conclusion: The FR and RT of the identified motor units showed a merely equal behavior in knees after sustaining a second ACL tear compared with those of the uninjured side. However, the motor unit control characteristics of the ACL injured knees can be related to the proportion of type I fiber area of vastus medialis muscle, which is in turn linked to the MVT.

O26.2 Hip Muscle Activation in Persons with PFP During The Side-Step Exercise: Is Resistance Important?

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Background & Aim: The TFL is an internal rotator of the hip and exerts a lateral pull on the patella, which may play a role in the abnormal mechanics associated with patellofemoral pain (PFP).(1,2) The SIDE-STEP exercise, when using elastic resistance, is beneficial for activating the gluteal muscles while minimizing activation of the tensor fascia lata (TFL) in uninjured persons.(3) However, it is not known if using elastic resistance is necessary with respect to the relative activation of the gluteal muscles versus the TFL. The aim of the current study was to determine if there is a benefit to adding elastic resistance to the SIDE-STEP for activating the gluteal muscles while minimizing TFL activation in persons with PFP.

Methods: Nine subjects with complaints of PFP, between the ages of 18-50 years, participated. EMG activity was assessed using fine-wire electrodes inserted into the TFL, middle gluteus medius (GMED), and superior gluteus maximus muscles (SGMAX). Raw EMG signals were sampled at 1,560 Hz with a bandwidth of 35-750 Hz. Subjects performed a SIDE-STEP exercise without elastic resistance, and with elastic resistance applied at the distal thighs. A metronome paced the movements. The mean root-mean-square (RMS) of the EMG signal in each exercise was normalized to MVIC, for each muscle. We utilized a previously described method to assess relative EMG activity of the gluteal muscles and TFL for each group, the Gluteal-TFL Activation Index (GTA).(3) The GTA Index was calculated using the normalized RMS of the TFL, MED, and SUP in the following formula: [(GMED/TFL) x GMED] + [(SGMAX /TFL) x SGMAX]/2 A higher index value is indicative of greater gluteal muscle activation relative to TFL. T-tests were also performed between exercises for each muscle to compare EMG activity levels.

Results: The GTA Index for the SIDE-STEP was 44.5 with elastic resistance, and 16.4 without. The comparisons between exercises for each muscle demonstrated that both SGMAX and GMED had significantly higher EMG activity in the SIDE-STEP with elastic resistance than without ($p<.05$). There was no difference in TFL EMG activity between the 2 conditions ($p>.05$). Table. EMG Activity (in %MVIC) Muscle Elastic No Elastic TFL 21.4 21.4 GMED* 33.3 20.3 SGMAX* 28.2 17.0 GTA Index 44.5 16.4 * significantly different ($p<.05$).

Conclusions: In persons with PFP, the addition of elastic resistance to the SIDE-STEP exercise resulted in higher gluteal EMG activity without increasing TFL activity. This is supported by the markedly higher GTA index for the gluteals compared to TFL, and the significantly higher EMG activity in the gluteals and no difference for TFL. As such, clinicians should consider using elastic resistance with the SIDE-STEP in persons with PFP.

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O26.3 An Investigation Into The MVIC And Surface EMG Median Frequency Of The Knee Extensor Muscles Measured In T2D Patients And Healthy Sedentary Individuals

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BACKGROUND AND AIM: Current evidence on the direct impact of type 2 diabetes (T2D) on neuromuscular function is conflicting. Recent studies have reported either no differences (1,3) or a reduction (2) in muscle maximal voluntary isometric torque (MVIC) and in muscle fiber conduction velocity (MFCV) of the vastus lateralis (1,3) between T2D individuals and sedentary healthy controls. Therefore, this present study aims to compare MVIC and median frequency (MDF) of the EMG signal, a surrogate of MFCV, of the quadriceps muscles of sedentary healthy and type 2 diabetic individuals.

Methods: 12 sedentary T2DM individuals (2 female, 52.83±7.06 years, 7.73±5.23 years disease duration) and 12 healthy but sedentary individuals (7 female, 47.75±9.13 years), participated in this study. An isokinetic dynamometer (Biodex System III, Biodex Medical System, NY, USA) was used to assess 3 maximal voluntary isometric contractions of the knee extensors at 60 degrees of flexion with 60 seconds rest between each contraction. During this, surface EMG was recorded from the vastus lateralis, rectus femoris and vastus medialis of the dominant leg using Ag/AgCl bipolar electrodes. EMG data were bandpass filtered from 20-350Hz (Chebyshev, n=4). The Teager-Kaeser energy operation was used to extract each of the 3 isometric contractions completed by each participant. The peak torque extracted for the isometric contractions. The MDF was for this repetition was then computed for each muscle, using a Fourier transform. Peak torque and MDF data were compared using a Mann-Whitney U test.

Results: No statistically significant differences were observed between groups for peak torque or the MDF of the 3 different quadriceps muscles assessed. Larger ranges in MDF were observed in the group with diabetes.

Conclusion: The near identical peak torques identified between the groups supports the previous work of Sacchetti et al. (3) and Bazzucchi et al. (1). However, the findings of the current study are not completely in line with that of Sacchetti et al. (3). Further high quality evidence is needed to confirm the exact effects T2D has on neuromuscular function. Table 1: Median frequency values of the surface electromyographic signal and peak torque recorded during maximal voluntary isometric contractions for the type 2 groups. Diabetic Group Non-Diabetic Group p-value VL (Hz) (± (SD)) 103.9 (29.2) 97.6 (7.2) 0.76 VM (Hz) (± (SD)) 108.2 (29.9) 100.2 (11.2) 0.50 RF (Hz) (± (SD)) 100.4 (29.3) 97.7 (7.2) 0.76 Peak torque (Nm) (± (SD)) 141.1 (39.5) 141.9 (40.0) 1

O26.4 Spatial dependencies of knee vibroarthrograms during knee flexion-extension movement

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Background and Aim: Vibroarthrography (VAG) of the knee joint has been known as a non-invasive diagnostic tool for more than 100 years. The VAG records vibrations and sounds emitted by the knee when it moves. Today, the technical advances enable to make multichannel VAG recordings of the knee during activities of daily living. The objective of the present study was to investigate spatial dependencies in six VAG parameters describing the amplitude, absolute and relative variability, frequency contents as well as periodicity of the VAG signals during knee flexion-extension. We hypothesized that the obtained VAG maps would delineate non-uniform distributions.

Methods: Eleven asymptomatic participants (8 males and 3 females) were recruited. The VAGs were recorded using a wireless multichannel VAG system. Eight accelerometers were attached around the right knee to record the VAGs during knee flexion-extension movement with 0, 1.25, 2.5, and 5 kg external load. The average rectified value (ARV), form factor (FF), variance of the means squared (VoMS), mean power frequency (MPF), percent determinism (%DET) and percent Recurrence (%REC) were calculated for each accelerometer location. A linear mixed model statistical analysis was carried out using load, movement type, and location as within subject factors. Interpolation maps of the parameters were created to illustrate their spatial distribution.

Results: The ARV, FF, VoMS, %DET and %REC changed significantly with increasing load, movement type (flexion and extension), and location. There was significant for load × movement type and location × movement type interaction for ARV and MPF, respectively. The maps of ARV, FF, VoMS, MPF, %DET and %REC were non-uniformly distributed and differed among each other.

Conclusions: The present study demonstrated spatial dependencies for the amplitude, absolute and relative variability, frequency contents as well as periodicity of the VAG signals during knee movement. The present approach enables investigations of activities of daily living in field environment in both asymptomatic and knee osteoarthritis population.

O27 MOVEMENT DISORDERS

O27.1 Myotonometry in spastic Cerebral Palsy: A pilot study on the effects of isometric contractions on biomechanical muscle parameters of the upper limb

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BACKGROUND AND AIM: Cerebral Palsy (CP) develops as a result of lesions to the brain, and is one of the main causes of early-onset motor deficiencies [1]. Isometric strength and strength training have been shown to positively correlate with function in children with CP [2]. However, the effect of voluntary isometric contractions on biomechanical muscle characteristics in participants with CP is not yet known. A better understanding of changes to mechanical muscle parameters after exercises may highlight the benefits of training for individuals with CP. This case-control study aims to compare muscle stiffness, tone and elasticity using a digital palpation device, MyotonPRO (Myoton AS, Tallinn), before and after a series of isometric contractions of the elbow joint.

Methods: A control group of 12 participants (6y-36y; mean: 22.09y; BMI 20.76kg/m2 ± 3.33 kg/m2) and a case group of 5 participants with CP (5y-31y; mean: 14y; GMFCS III: 1, GMFCS IV: 2, GMFCS N/A: 2; BMI 20.05kg/m2 ± 5.74kg/m2) were recruited for the study. The maximum elbow flexion torque was evaluated at a standardized angle of 80°, using a load cell and a custom elbow device (Figure 1). This elbow angle was shown to result in the highest torque output of the elbow flexors in preliminary studies using OpenSim. Subsequently, the subjects were asked to perform two low (15% of maximum flexion force), medium (30%) and high (70%) force ramps, while real-time force feedback was provided on a computer screen. Myotonometry was performed before and after the isometric force trials on the Biceps, Brachialis, Extensor Digitorum and the Triceps of the dominant arm (or the more affected arm in the case group). Between-group differences in the change in selected muscle parameters (tone; stiffness; elasticity) were evaluated using independent samples t-tests.

Results: The change in muscle tone and stiffness of the Biceps muscle was significantly different between groups (muscle tone: $p = 0.027$; CP: -0.31Hz ± 0.77Hz, non-CP: 0.92Hz ± 1.98Hz; stiffness: $p = 0.047$; CP: -5.73N/m +- 19.23N/m non-CP: 20.4N/m +- 48.80N/m). No significant differences were found for elasticity, or in the other muscles examined.

Conclusions: Preliminary results suggest the muscles of individuals with spastic CP might adapt differently to isometric contractions than those in individuals without CP. Participants with CP demonstrated a greater reduction in muscle tone and stiffness compared to the control group, however this finding was limited to the Biceps muscle only. Studies using the MyotonPRO on larger, age and gender-matched populations are required to provide reference data for muscle adaptations after sustained isometric contractions. This could be beneficial to monitor therapy and rehabilitation effectiveness. [1] Graham et al. Nat Rev, 2, 2016. [2] Rameckers et al. Res Dev Disabil, 36: 87-101, 2015.

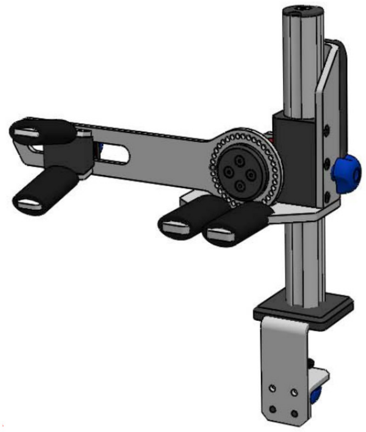

Figure 1: Custom elbow device to record the torque output of the elbow joint. The height and length of the device can be adjusted t ts' anthropometry.

O27.2 Saccade Behaviour in Cervical Dystonia

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Background & Aim: The superior colliculus (SC) plays a critical role, in saccade generation and attentional orienting. Express saccades, short latency reflexive saccades, are generated by the SC, as evidenced by studies of both primates and humans. Cervical dystonia, a hyperkinetic movement disorder, is the most common form of adult onset dystonia. The etiology of cervical dystonia remains unknown; increasing evidence supports the hypothesis that dystonia is a network disorder within which the SC is a key node; abnormally low gamma-aminobutyric acid (GABA) activity may be a critical factor. This study explores saccadic eye movements in cervical dystonia and age-matched healthy control participants as a means of probing neuronal behavior in the SC. We hypothesized that cervical dystonia patients, compared to controls, would have a higher incidence of express saccades in the Pro and Gap tasks with an increased error rate in the anti-saccade task.

Methods: Six cervical dystonia participants (49-64 years), and five control subjects (49-65 years) participated in this study. Subjects were seated in a completely dark room with their chin on a chin rest. Electrooculography (EOG) was recorded using a BioSemi system. Three paradigms, custom coded in Presentation (Neurobehavioural Systems) were presented on a computer monitor 60 cm in front of the chin rest: Pro-saccade (120), Anti-saccade (2x60), and Gap (120), total 360 trials per subject. Target stimuli appeared at 100 randomly to the left and right. Custom software was developed which enabled consistent offline analysis: the EOG was bandpass filtered and EOG velocity, saccade onset, saccadic reaction time (SRT), directional errors and occurrence of blinks were determined for each trial.

Results: There was a significant impact of task type on SRT for both the control and patient groups (p-values, 10-6-10-34), Figure 1. Group median SRT values (controls, patients) in ms were Pro (154.3, 148.4), significantly different (F=13.26, p=0.0003), Gap (107.7, 116.2), and Anti (264.2, 249.0). The percentage of express saccades (SRT of 50-120 ms) were Pro (26.1, 22.1), Gap (64.1, 62.5). The percentage of directional errors while low in the Pro (1.8, 0.4) and Gap (1.3, 0.5) paradigms for both controls and patients, were much higher for the anti-saccade task, as expected (11.8, 6.9).

Conclusions: Anticipated differences in control and patient data have not been revealed by these pilot data. Low GABA would be expected to reduce SRTs giving rise to higher than normal % express saccades in the gap and pro tasks, and greater levels of directional errors in the anti-saccade task. Do our findings imply that: the proposed hypothesis for the etiology of cervical dystonia is inaccurate? Saccadic studies are not an appropriate means of assessing this etiology? Or is this result merely a product of the as yet relatively small dataset? Further research is required.

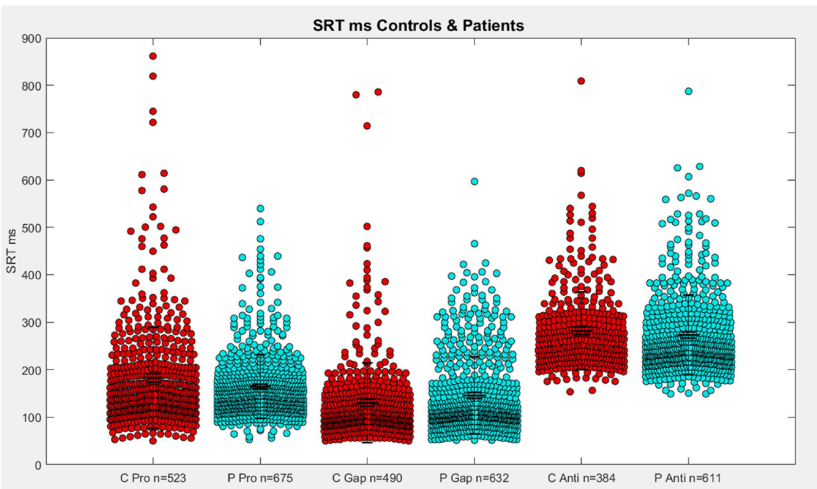

Figure 1: Population behaviour (all observations) of SRT for correct saccades (in the expected direction) across the three tasks. 'C' denotes controls (red) and 'P' denotes patients (blue). No SRTs<50ms accepted. The number of trials included in each population is represented b 'n'.

O27.3 Monitoring Movement Disorders in Parkinson's Disease

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BACKGROUND AND AIM: Movement disorders associated with Parkinson's disease (PD) pose challenges for effective management due to their diversity, temporal variability, and complications from levodopa treatment. Recent advances in sensor technology hold promise in meeting these challenges but have not advanced beyond tracking only a subset of motor symptoms during standardized scripted activities. There remains a need for new technology that can autonomously track changes in the presence and severity of a more complete set of motor disorders associated with PD during unscripted activities of daily living.
Methods: We have designed a comprehensive movement disorder tracking system that uses body-worn sensors and AI algorithms to: 1) detect the incidence of different PD symptoms such as bradykinesia, tremor and dyskinesia during unscripted daily activities, and 2) provide clinical metrics that can be directly interpreted by the clinician to inform changes in the severity of these manifestations over time or in response to medication. The system uses recordings of surface electromyographic (sEMG) and inertial measurement (IMU) signals to capture the unique muscle activity and movement characteristics of different motor impairments. To resolve the complex, activity-dependent manifestations of symptoms throughout a broad-range of unscripted activities, we designed a neural network activity classifier to first separate walking from non-walking activities that are subsequently provided to dynamic neural network algorithms to detect PD motor manifestations. In addition to the inputs to classification algorithm, we used clinically informed metrics to provide a quantitative means for assessing the severity of each symptom. We evaluated our system of Trigno IM (Delsys Inc, Natick MA) sensors and automated algorithms during 3-hour experiments of monitoring unscripted activities with n = 29 PD patients (Age 60.8 ±11y) who manifested a range of PD symptoms across different stages of disease progression (Hoehn and Yahr 1-3). Sensors were placed on extensor digitorum (ED) muscle of upper arm and tibialis anterior (TA) muscle from lower leg from the more symptomatic side of the body. Expert annotations identified by movement disorder experts provided different activity states and symptom scores (UPDRS) for training the detection algorithms.

Results: Our system was able to successfully detect the different motor manifestations of PD with 93.1% mean accuracy across all the patients tested. We further found that the temporal variations in clinically informed metrics indicated clear changes in the manifestation and severity of the PD symptoms with medication (on-off) phases.

Conclusions: These results demonstrate the viability of a body-worn system that can be used to detect and quantify a variety of movement disorders related to PD during unscripted daily activities. Supported by NIH/NINDS R44NS083098 and the De Luca Foundation.

O27.4 Muscle activation in most versus least affected side in patients with Parkinson's disease.

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Background and aim: Parkinson's disease (PD) is associated with disturbance in motor control and increased co-activity during submaximal tasks compared to healthy subjects. Furthermore, muscle weakness due to central activation deficit may occur in advanced PD (1, 2). Asymmetric functional level, with a most affected side (MA) and a least affected side (LA), is common in PD. However, our knowledge regarding muscle activation and muscle strength in relation to asymmetry in PD is sparse. The aim was to study maximal muscle activation and grip strength as well as contralateral co-activation in the MA side compared to the LA side in PD. Method 18 patients (13m/5f, age 66.2yrs., body weight 74.8kg, height 1.73m) with mild to moderate PD (UPDRS-motor: 26, range 4-61) performed 3-5 maximum handgrip contractions with left and right hand. Right side was the MA side in 10 patients. Surface EMG was recorded from wrist/finger extensor, wrist flexor and the anterior deltoid muscles, bilaterally. RMS amplitudes were calculated and EMGmax determined as moving average across 1sec. The patients were optimally medicated and their medication had not been changed at least 6 weeks prior to participation. Measurements were performed with the patient in self-reported on-phase.

Results: Hand grip muscle strength in MA and LA side was 38.8kg and 37.2kg, respectively. Extensor muscle EMGmax for the MA/LA hand was 355µV/359µV. Flexor muscle EMGmax for the MA/LA hand was 248µV/233µV. Ipsi-lateral co-activity of the deltoid muscle was 139µV/152µV for the MA/LA hand. Contra-lateral co-activation of the extensor muscles were 13% for LA and 20% for MA side. Contra-lateral co-activation of the flexor muscles were 31% for LA and 32% for MA side. No significant differences of strength and activation between MA and LA side were found for maximum handgrip contractions.

Conclusion: Asymmetric motor ability in PD cannot be explained by a side specific decreased capacity of neural drive to the muscles in mild to moderate affected patients with PD. Furthermore, no side differences were found in contralateral co-activation of the forearm muscles during maximum handgrip contractions. These data support the idea that other factors such as e.g. side differences in motor control with a less effective activation patterns rather than side differences due to failure in ability to generate muscle force and central activation capacity explain asymmetric upper extremity motor function in mild to moderate affected PD.

Ref: (1) Stevens-Lapsley J. et al. Neurorehab. & Neural Repair (2012);26(5):533-541. (2)Cano-de-la-Cuerda R. et al. Am. J. Phys. Med. Rehabil (2010);89:70-76

O27.5 Dynamic Movement in Parkinson's Disease Quantified Using Nonlinear EMG Features

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BACKGROUND & AIM: Clinical scores such as the UPDRS score, 30s Sit-to-Stand (STS), and 10m Walking Test (10MW) are limited in their capacity to characterise specific kinematic adaptations that occur in PD [1]. This limitation becomes critical when scores are used to evaluate the efficacy of physical therapies, where more objective quantitative methods may apply. Previous studies employing recurrence quantification analysis (RQA) and sample entropy (SampEn), have shown differences between EMG features of PD and controls during isometric contraction, potentially related to increased motoneuron synchronization in PD [2,3]. The aim of this study is to determine whether similar differences are evident in EMG features of PD and control groups during dynamic contractions, performed in the STS and 10MW tests.

Methods: EMG was recorded from seven muscles in each leg during STS and 10MW tests in 11 healthy controls (67 ± 4 yrs.) and 8 PD patients (74 ± 6 yrs.) before and after a 4 week physical therapy programme. Features of the gait and STS cycles were identified from accelerometer data recorded at the L5 vertebra [4], and upper leg [5] respectively. An epoch of EMG data from each of the first 5 cycles of both tasks was extracted and resampled to maintain a uniform signal length. Recurrence rate (%REC), determinism (%DET) and SampEn were estimated from each epoch and averaged across both legs.

Results: The total number of Sit-to-Stand transitions in the PD group pre-therapy was significantly lower than the control group ($p = 0.031$). Total 10MW times of the PD subjects post-therapy were significantly lower than controls. Mean step, stride and swing times reduced within PD subjects in response to therapy, reflective of significant improvements in MDS-UPDRS motor scores ($p = 0.02$). In the STS task, SampEn of EMG from the rectus femoris and semitendinosus were significantly lower in the PD group post-therapy than controls (RF: $p = 0.028$, ST: $p = 0.011$). In the 10MW task, SampEn of EMG of biceps femoris and semitendinosus muscles was significantly lower in the PD group pre and post-therapy when compared with controls ($p < 0.005$).

Conclusions: Lower SampEn of EMG in the PD group is indicative of greater structure in the EMG signal, potentially related to increased motoneuron synchronization and is consistent with results of previous studies of EMG during isometric contraction in PD. Although no consistent differences in %DET were observed between groups, an optimization analysis of RQA parameters for dynamic contractions may yield results similar to SampEn. These EMG features which are altered in PD, could potentially aid clinical assessments by providing a quantitative measure of neuromotor control strategies.

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O27.6 Effect of rhythmic auditory cueing on muscle synergies in people with Parkinson's disease: A pilot study

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BACKGROUND AND AIM: PD is characterised by motor dysfunction such as gait impairment, which increases the risk of falls and disability [1]. Atrophy of dopaminergic neurones in the substantia nigra leads to loss of automaticity during walking [2]. Functional benefits of automaticity include improved dual task performance. Auditory rhythmic cueing (ARC), a rehabilitation technique, may normalise stepping through auditory feedback [3] and promote motor learning to improve gait function. However motor control strategies associated with ARC are unknown. This study aims to analyse lower-limb muscle synergies during walking with ARC which may reveal motor control strategies employed by people with PD.

Methods: Data analysis was performed on a subsample of 16 participants (8 healthy older adults (HOA) (74 ± 7 years, 47% female) and 8 with PD (70 ± 4 years, 37% female) drawn from a larger study. Wireless surface electrodes (Cometa, Bareggio (MI) Italy) measured lower limb muscle activity bilaterally from two groups: dorsiflexors (tibialis anterior) and plantarflexors (medial gastrocnemius, lateral gastrocnemius and soleus). Participants walked overground for 300 seconds in alternating 30 second bouts of usual walking (UW) and ARC walking. Muscle synergies were determined using non-negative matrix factorisation and the number (NVAF) calculated that accounted for 90% of overall variance [4].

Results: Non-parametric tests showed no significant differences ($p>0.05$) in NVAF between the PD group (3-6 NVAF) and HOA (3-5 NVAF) during UW. NVAF increased in 3 participants with PD, who had greater fear of falling scores, when ARC was applied during walking whilst no increase was observed in HOA. The plantarflexors had greatest weighting on synergies 1 and 2, whilst the dorsiflexors contributed most to synergies 3 and 4 in both groups and walking activities. A change in muscle weighting on the first 2 synergies was observed in the PD group, with right plantarflexors dominating during UW changing to left plantarflexors during ARC walking.

Conclusions: Given that 4 muscle groups were analysed, 4 synergies were expected to account for 90% variance. Increased NVAF following ARC suggests ARC promotes more complex motor strategies to normalise stepping in people with PD.
Results suggest that individuals with higher fear of falling scores benefit most from ARC. The change in composition of the first 2 synergies in the PD group during ARC walking suggests asymmetry is targeted, which is commonly present in PD. Analysis of the remaining experimental cohort will provide higher power for more robust statistical testing.

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S14 SYMPOSIUM: MOVING BEYOND THE PHYSICAL: ADDRESSING MUSCULOSKELETAL INJURY INDUCED NEUROPLASTICITY AND MOTOR CONTROL TO IMPROVE PATIENT-FUNCTION

S14.1 Clinically Targeting Neuroplasticity in Rehabilitation

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Injuries of the anterior cruciate ligament (ACL) are one of the most common and devastating sports injuries. For young athletes (< 25 years of age) returning to competitive sports involving jumping and cutting activities, second ACL injury rates of 23% have been reported, especially in the early return to sport (RTS) period. Based on the afore mentioned background it is apparent that traditional rehabilitation does not facilitate to restore normal motor function in patients after ACLR. Components of current rehabilitation programs entail a combination of exercises to increase muscle strength, improve balance and endurance whilst reducing neuromuscular deficits. The purpose of this presentation is to present new perspectives from motor learning applied to clinical settings that have the potential to improve rehabilitation strategies and subsequent outcome for patients after ACL injury. The following key concepts may enhance rehabilitation by targeting movement asymmetries and prepare the patient for a safe as possible integration to sports after an ACL injury: 1. External focus of attention 2. Implicit learning 3. Differential learning 4. Self controlled learning and contextual interference

S14.2 Neuroplasticity after Musculoskeletal Injury

Dustin R Grooms[1], Jochen Baumeister[2], Jae Yom[1], Alli Gokeler[3], Janet Simon[1]
[1]Ohio University, [2]Paderborn University, [3]University Medical Center Groningen

The study of neuroplasticity as applied to sports medicine is a relevantly new area of research. The classical view of orthopedic or musculoskeletal medicine has been to treat the local joint and surrounding muscular. This approach has led to primarily a structural and mechanical view of the field and while that has yielded immense strides in the understanding of the biomechanical implications of tissue properties and motor function that may increase tissue failure, it left the field with little by the way of how to train the human neural system to improve motor performance and especially in the cognitively challenging and sensory rich sport environment. In this session we will overview the foundation of neuroscience integration into sports medicine research and practice. Starting with how what was once thought of as a purely structural injury induces neuroplastic effects and transitioning to how those effects alter motor performance, biomechanical injury risk and finally how clinicians can embrace neuroscience to improve patient function and outcomes.

S14.3 Patient-Outcomes to ensure Optimized Patient-Function

Janet E Simon
Ohio University

The gold standard in determining a successful outcome after a musculoskeletal injury is patient-reported. Injury, illness, and recovery contain subjective components, not just objective measures. Every injury has the potential to affect the psychological, social, and even spiritual aspects of life not just the physical. If we ignore measuring patient-reported outcomes during clinical assessment, we are not treating the whole patient. The utilization of patient-reported and clinician based outcomes are essential to the provision of whole-person, patient-centered care. These information are not only valuable when monitoring patient progress but also are able to guide clinical decision making, and return to play decisions. Furthermore, the ability of clinician-based measures (e.g. single-leg hop for distance) at return to play may be able to predict future patient-based outcomes and a successful return to function. Therefore, the goals of this presentation will 1) discuss selection, implementation, scoring and application of patient-reported outcomes in to clinical practice and decision making, 2) review region and generic instruments that are often utilized in patient populations who have sustained knee injuries, and 3) discuss the utilization of clinician based outcomes, specifically limb symmetry indices (LSI) in rehabilitation and clinical decision making and their relationship with patient-based outcomes.

S14.4 Motor Performance changes after Musculoskeletal injury

Jae Yom
Ohio University

An anterior cruciate ligament (ACL) injury is a common and debilitating musculoskeletal lower extremity injury. Understanding how changes in motor performance during unanticipated events may provide insight into the detrimental effects of altering motor performance on biomechanics. In addition, the ACL-injured population is at an increased risk of developing osteoarthritis compared with an equivalent, uninjured population. This increased risk is likely due to mechanical alterations brought about from damage to the musculoskeletal system and changes due to surgical intervention. It is also likely that changes in motor performance post-injury may contribute. Accordingly, decreasing the rate of ACL injury is of high importance and most ACL injury-related research has focused on ACL injury risk factors and/or injury mechanisms. Thus, understanding biomechanical adaptions due to changes in motor performance both during the athletic performance and after ACL injury/surgical repair would provide a comprehensive understanding of the consequences of prevention programs and rehabilitative regimens for athletes. Therefore, this presentation will 1) discuss novel applications of motor control with perturbations related to ACL injury risk and 2) review the literature on motor control changes after ACL injury.

S14.5 Translating Neuroplasticity to Motor Performance

Jochen Baumeister
Paderborn University

Musculoskeletal injuries can lead to altered functional and structural organization of the brain. The modification and re-organization of this brain function after the injury is based on neuronal plasticity, which is a crucial part of recovery and return to play protocols. Potential biomarkers measured by electroencephalography may be able to monitor an adequate neurophysiological load during exercises to ensure a successful rehabilitation process after musculoskeletal injuries. This will help to build a sensorimotor training framework, which will include variations in different sensory `environments and conditions based on principles of neuroplasticity. Overall, this talk will try to elucidate, how training as a potential stimulus of neuroplasticity might be used to enhance plasticity as a foundation of recovery after injuries and increase in performance.

S15 SYMPOSIUM: NEUROMECHANICS OF LOWERLIMB AMPUTATION AND PROSTHETIC GAIT

S15.1 Muscle synergies of the contralateral lower limb in trans-femoral amputees gait

Cristiano De Marchis, Simone Ranaldi, Silvia Conforto
University Roma TRE

INTRODUCTION: The analysis of the modular structure underlying the neuromuscular control of movement has been used as a tool for the assessment of the features of pathological gait. Muscle synergy analysis can be useful for the characterization of the adaptation strategies in trans-femoral amputees' (TF) gait. Previous research has shown that TF gait is characterized by an anomalous activity of several muscles, especially during the contralateral single support phase. In this work, the activity of 12 muscles of the sound limb during gait has been recorded for a complete characterization of the muscle synergies in TF subjects.

MATERIALS AND METHODS: All the experimental protocol has been carried out at the Rome branch of the INAIL prosthetic centre. A population of healthy subjects (58.5 ± 12 years old) and 16 trans-femoral amputees (52.5 ± 15 years old, wearing different kinds of prostheses) participated in the study. sEMG data have been recorded during 12 trials of walking at a self-selected speed along a 9m walkway, together with the kinematic data used for the segmentation of the sEMG recordings. sEMG data have been time normalized over 100 samples for both stance and swing phase independently, as to avoid misinterpretations due to the different ratio between stance and swing phases, which is altered in amputees. Muscle synergies were extracted by means of Non-Negative Matrix Factorization (NNMF), as to obtain synergy vectors W and synergy activation coefficients C.

Results: Gait coordination in both control and TF population has been found to be explained well by the activity of 4 synergies. The spatial structure of the synergies is similar between the two populations (average normalized scalar product > 0.8), and the modules extracted from each population have been able to reconstruct with good quality the activity of all the subjects belonging to the other group (using Non-Negative Reconstruction). Two modules have been found to be activated with substantially different shapes and during different phases of gait, while all the four modules show a slightly delayed activation in TF with respect to the control group.

Conclusions: Results give evidence that healthy and TF control strategies are characterized by the same spatial composition of modular motor control. The different activation profiles found for the calf and the antigravitational synergies might reflect a response to the altered biomechanical demands that the neuromuscular system must satisfy in order to reach a stable gait pattern. A complete characterization of the functions assumed by each module can be reached by comparing these results with a complete kinematic and kinetic analysis. These results pave the way to differentiate the effect of different types of prostheses as well as of different stages in the rehabilitation process, in order to provide a quantitative indication for a proper choice of the prosthetic device and for the most adequate treatment.

S15.2 Kinetic and kinematic patterns for prosthetic gait analysis

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The walking training process in amputee subjects with prosthetic devices requires complex adaptation strategies in both the prosthesis side and the non-amputated side. Thus, prosthetic gait reflects a mixture of deviations, adaptive and compensatory motion dictated by residual functions in a new anatomical condition. Essentially, the main feature of the unilateral prosthetic gait is the asymmetry in both kinetic and kinematic parameters. Each subject, due to the different types of amputation (transfemoral, transtibial), prosthetic device (electronic, mechanical), individual adaptation, presence of pain and so on, has his/her unique gait pattern. This creates heterogeneity and affects our understanding on the essence of the gait disorder. Quantitative 3-dimensional gait analysis is the best way to understand the complex multifactorial gait dysfunction in amputee subjects (Baker et al., 2006) and to distinguish what is unique from what is common. The aim of the present study was to give a global and functional view of the prosthetic gait by considering both the upper and lower body motion, gait harmony, energy consumption, dynamic balance as well as segmental and global kinetic and kinematic variables in a sample of amputee subjects. We found common gait patterns related to some clinical characteristics (e.g. type of amputation) which can be of value in determining the most meaningful gait features in the complexity of locomotion and thus in shedding light on the nature of both the primary specific gait disorder and its compensatory mechanisms. Remarkably, the increased upper body oscillation is an integral part of the gait disorder in amputees and is used, as movement generator, to maintain a good level of gait performance. Interestingly, amputee subjects, as result of the lack of their gait symmetry, dynamic balance and anatomical integrity lose the so called harmony of gait, as also reported for other several gait disorders (Iosa et al. 2017; Serrao et al., 2017). We think that such deeper understanding in the prosthetic gait might represent a reasonable prerequisite for establishing better-focused rehabilitation and walking training in amputees.

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S15.3 Quantitative indexes for assessing lower limb muscle co-activation in amputated subjects.

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In unilateral lower limb amputees, prosthetic devices supplant the missing limb acting in series with the residual limb. The most common causes of an altered gait pattern in these subjects are inadequate rehabilitation, prosthetic alignment and leg length discrepancies. Improving the gait performance increases the residual limb comfort and reduces compensatory strategies that, over time, may imply damages. Unfortunately, only few studies have investigated the effects of rehabilitation and prosthetic components on gait performance in people with unilateral lower limb amputation. In these studies kinematic, kinetic and surface electromyography (sEMG)-based parameters are usually used in computerized gait analysis for quantification, evaluation, and comparison aims. Among sEMG-based parameters, the simultaneous activation (co-activation) of muscles of the uninvolved lower limb joints has been investigated. Co-activation regulates the time and amplitude of concomitant activity of muscles around the same joint. It has been shown that co-activation increases in patients affected by several gait disorders [1, 2]. Muscle co-activation has been measured by means of sEMG by using mathematical tools derived from an agonist-antagonist approach based on the ratio, overlapping or cross-sectional areas below the sEMG signals recorded from two antagonist muscle groups. However, muscle co-activation at a single joint does not provide a full understanding of the global strategy adopted by the central nervous system in controlling the uninvolved limb. During gait rehabilitation and in choosing mechanical, electronic and bionic prosthetic components, a global analysis of the uninvolved lower limb muscle co-activation may be helpful to understand changes in the motor strategy adopted by amputees in relation to the gait balance, speed and energy consumption. In this study the global muscle co-activation of the uninvolved limb in a sample of unilateral amputees by using the time-varying multi-muscle co-activation function (TMCf) [3] was calculated. Time-varying monitoring the co-activation of more than two muscles (multi-muscle), belonging to the uninvolved lower limb in people with unilateral amputation does not require an a-priori classification (agonist or antagonist) of the muscles depending on the generated moment.

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S15.4 Indexes for the Functional Evaluation of Dynamic Stability in Amputees Gait

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INTRODUCTION: Stability and balance keeping are extremely important aspects of gait for functional, safety and psychological reasons. Assessing and quantifying stability and risk of fall could be of great importance in the field of rehabilitation medicine for the functional gait recovery of amputated subjects; amputation of a lower limb requires the patient to face a completely new biomehcanical demand and to adapt to the new prosthetic gait condition. The present study aims at finding an eligible method for gait functional evaluation in lower limb amputees, able to provide an overall reliable information on stability and risk of fall also in short duration evaluation sessions, more adequate for amputated subjects. Different indexes are calculated based on kinematic data, and their ability to discriminate among populations and highlight alterations in gait behavior is analyzed.

Methods: Data were collected in a Movement Analysis Laboratory at the Rome branch of INAIL Prosthesis Centre. The experimental setup consisted in 6 infrared cameras (BTS Bioengineering, Smart DX6000). Passive markers were placed according to Davis's protocol. Each participant performed 12 walking trials along a 9m walkway. Kinematic data were recorded from 19 trans-femoral amputees (TF, range 29-74 years), 9 trans-tibial amputees (TT, range 34-80 years) and 12 healthy controls (H, range 29-77 years). Kinematics have been used to compute the centre of mass (CoM). Obtained CoM's traiectories were used to compute the Margin of Stability (MoS), together with gait symmetry and regularity, computed along the AnteroPosterior (AP), Medial-Lateral (ML) and Cranial-Caudal (CC) directions using the autocorrelation of the CoM acceleration signal.

Results: Amputees showed a significantly wider margin of stability than controls, both along AP and ML directions. Furthermore, amputees presented a significantly more asymmetric and less regular gait than controls along all the three analyzed directions. Despite the substantial differences in biomechanical demands and used prosthetic device, no significant differences were found between TT and TF in terms of stability parameters.

Conclusions: MoS analysis might indicate differences in motor control strategies between amputees and healthy subjects: specifically, a wider MoS (resulting from a wider base of support and a lower gait speed) could compensate the lower balance control abilities in such patients. The higher gait asymmetry and irregularity in amputees show, furthermore, how such patients have a reduced motor control, resulting in a less standardized and noisier gait pattern. Although the studied parameters don't represent effective estimator of the risk of fall, they could give an overall functional characterization of gait, and could be used in clinical environment to improve therapies and design of prosthetic devices, starting from basic information such as stability and motor control.

S15.5 Neuro-Mechanical Indicators Of Amputees Rehabilitation

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In its last three-year research plan, INAIL has set itself the goal of identifying new biomechanical indicators of the results of the rehabilitation process in patients with lower limb prostheses. INAIL with its Rehabilitation and Prosthetic Centers is highly engaged in this sector. Although many tools are offered for clinical purposes, a gold standard is not yet available. The aim of the collaboration between INAIL, Roma TRE University and Sapienza University of Rome is to identify neuro-mechanical indicators to evaluate the effectiveness of the rehabilitation process in patients with trans-femoral amputation and with different kinds of prostheses. The current wide availability of motion analysis laboratories allows integrating instrumental quantification with clinical evaluation methods already in use to study the correlation between the most used scales for clinical evaluation and neuro-mechanical indicators. The identification of significant biomechanical indicators, related to kinematic and dynamic parameters, will focus in particular on temporal parameters, joint angles, covariance planes of segmental elevation angles and load management in the support phase. In order to achieve a complete neuro-mechanical assessment, we studied the modular motor control in the non-amputated lower limb of prosthetic patients who underwent trans-femoral amputation, at different stages of the functional recovery. The indicators related to the neural control were extracted from the analysis of muscular synergies (number of synergies, spatial structure of the modules, morphology and timing of the synergies activation profiles), and allowed us to identify differences in the modular organization of trans-femoral amputees and allowed a neuro-mechanical description of amputees' gait. The main differences were observed in the muscle recruitment profiles and they can be interpreted as a necessary compensation strategy during the swing phase of a prosthetic limb. Further studies will allow us to better describe the rehabilitation process of prosthetic patients providing the therapists with quantitative data.

O28 SENSORS

O28.1 Developement and Testing of Hydrogel-Based EMG Electrodes Transparent to Ultrasounds

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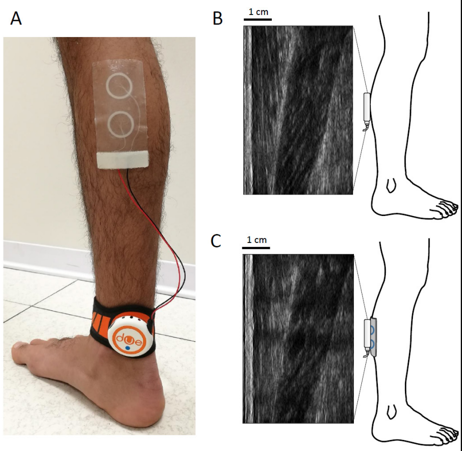
BACKGROUND AND AIM: Electromyograms (EMGs) and ultrasound (US) images provide complementary information on muscle function. A combined EMG-US approach allows for the electromechanical characterization of muscles, from the neural excitation to the resulting muscle tissue displacement, and their possible adaptations with aging, rehabilitation, neurological disease, and injury. Currently, it is not possible to detect US images and EMGs from the same muscle region with commercially available electrodes. The purpose of this study was to develop and test a bipolar EMG electrode for simultaneous acquisition of ultrasound images and surface electromyograms (sEMGs) from the same muscle region.

METHODS: The electrode, hereafter referred to as bEMG-US, consists of two circular sensing regions (20mm diameter) with fixed inter-electrode distance (3.5 cm, center-to-center) (Figure, A). Both the sensing regions and the external structure of the electrode are made of hydrogel layers separated by insulating materials. The electrical properties of the bEMG-US electrode (i.e. impedance and noise of the electrode-skin interface) and the quality of sEMGs detected over the medial gastrocnemius were assessed and compared against those of commercially available EMG electrodes with the same size, shape and inter-electrode distance. The effect of the bEMG-US electrode on the quality of US images during concurrent acquisitions of sEMGs and US was evaluated by comparing US images detected from the same muscle region with and without the electrode between the US probe and the skin.

RESULTS: Tests on five subjects showed that the electrode-skin impedance of the bEMG-US electrode was higher than that of conventional EMG electrodes (mean (range): 15.6 (8.5 - 21.1) kΩ vs 8.2 (4.9 - 16.5) kΩ). Despite higher impedance values, the RMS noise of the electrode-skin interface was similar (1.4 (1.1 - 1.7) µV vs 1.3 (1.0 - 1.7) µV) and the M-waves detected by the two electrode types were comparable (normalized mean square error: 2.6 (0.6 - 6.8) %). Visual inspection indicate US images detected with and without the bEMG-US electrode between the US probe and the skin were comparable (Figure, B and C), which possibly explain the low errors in the estimation of anatomical variables in the two experimental conditions (range: (0.37-2.35) deg for pennation angle and (-0.31-0.1) cm for muscle thickness).

CONCLUSIONS: Results demonstrate that bEMG-US can be used to acquire concurrently sEMGs and US images from the same muscle region with a negligible effect on the quality of the two detected signals thus allowing for a simultaneous, multimodal evaluation of muscle activation.



bEMG-US electrode positioned over the medial gastrocnemius (A). US images detected from the central part of medial gastrocnemius in two experimental conditions: without (B) and with (C) the presence of bEMG-US electrodes between the US probe and the skin.

O28.2 Design and validation of a modular and wearable High-Density sEMG acquisition system

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BACKGROUND AND AIM: In the last two decades it has been demonstrated that bipolar sEMG signals are highly affected by many confounding factors difficult to manage [1, 2] and High-Density sEMG (HD-sEMG) techniques gained importance. Few wearable HD-sEMG amplifiers have been proposed in literature [3, 4] and some are commercially available but the need for cable connection between the electrodes and the amplifier and the size and weight of such devices limit sEMG recordings in dynamic conditions. The aim of this work was the development of a miniaturized, wireless HD-sEMG acquisition system as a tool for enabling new research frontiers in the non-invasive analysis of neuromuscular system.

Methods: The system architecture was designed to be modular and scalable. The core of the system is a wireless miniaturized 32-channels sEMG amplifier (Sensor Unit - SU) that can be used as a node of a network for the monitoring of different muscles. Each SU performs the conditioning, sampling, and wireless transmission of 32 monopolar sEMG channels, sampled at 2048ksps with 16 bit resolution. The SU wirelessly transmits the acquired signals to either a mobile device or a personal computer for real time visualization and storage. Signals are transmitted to the receiver via a direct link (point-to-point connection) when only one SU is used or through an access point when more than one SU are used. Two or more SUs can be synchronized and used at the same time. A standalone software was developed for the acquisition and online visualization of the sEMG signals on the receiver. The developed system has been tested in clinical and sport scenarios (ranging from the gait analysis to biking, to jumping).

Results: Two prototypes have been mounted and encapsulated in a 3D printed case. The total encumbrance of an SU is 3.4cm x 3cm x 1.5cm with a total weight of 16.7g. A network of two SUs has been successfully tested (Figure a) and the system allowed continuous acquisition for up to 5 hours. The experimental tests performed in a wide spectrum of conditions from isometric to highly dynamic tasks show the system can be easily worn and does not interfere with subject’s movements. The signals acquired in monopolar mode are free from power line interference (Figure b, c). Movement artifacts that frequently affect the signal quality during dynamic contractions are almost absent even during highly dynamic tasks such as vertical jump (Figure d, e, f) thanks to the absence of connecting cables between the electrodes and the acquisition system.

Conclusions: The developed wearable wireless 32-channel sEMG system opens new perspectives in the use of HD-EMG in dynamic conditions for the study of neuromuscular system.

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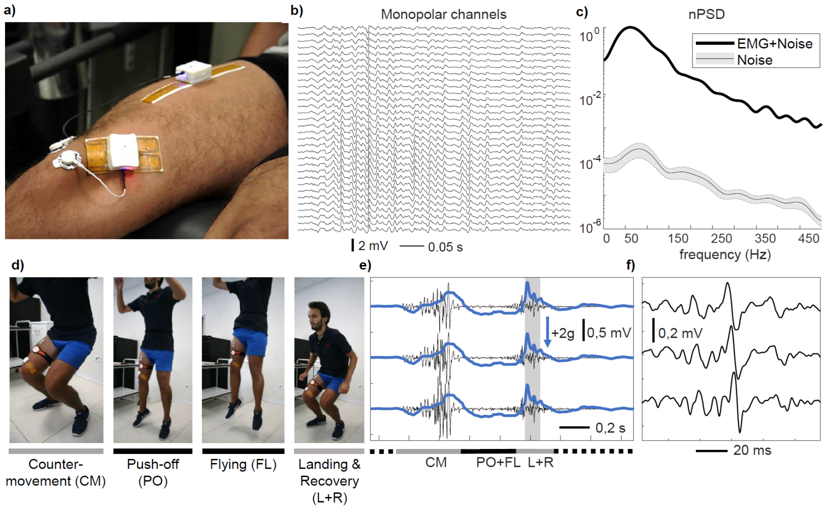

a) Experimental setup showing two systems acquiring 32 sEMG signals each from the Vastus Medialis (VM, 8x4 electrodes grid, IED 10mm) and Rectus Femoris (RF, 32 electrodes array, IED 5mm) muscles; b) Monopolar signals collected from the RF muscle during knee extension; c) normalized PSD of the collected signals and noise; d) Validation of the system during jumping: different jump phases are shown; e) Three Single Differential signals collected from VM muscle (black) and vertical acceleration (blue) during one jump; f) Zoom on MUAP propagation.

O28.3 3D Printing and Subsequent Evaluation of Novel Microneedle Electrodes for Surface Electromyography

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INTRODUCTION: Surface electromyography (sEMG) is an important diagnostic technique involving recording of electrical signals generated during muscle activity. Often, wet Ag/AgCl electrodes are used to pick up this signal. The outer stratum corneum layer of the skin presents a high impedance and therefore an electrolyte gel is applied before placing the electrodes to increases conductivity across the skin. Over time however, the gel may dry up resulting in decreased signal quality [1]. Wet electrodes are also susceptible to motion artefacts [2], especially during dynamic activity.
Novel microneedle electrodes (MNEs), which comprise of micron-sized protrusions, may prove advantageous compared to conventional electrodes. Microneedles pierce through the stratum corneum, reducing the overall impedance. This may increase signal quality and eliminates the need for an electrolyte gel as well as prior skin preparation. Long-term sEMG measurements are thus enabled and dermal irritation risks associated with skin preparation decreased. MNEs may also decrease motion artefacts by mechanically anchoring into the skin, resulting in a more stable signal during dynamic muscle activity.
Expensive and complex MEMS fabrication techniques are often used to fabricate MNEs developed to-date. Here we present a method for the design and fabrication of MNEs by employing direct metal laser sintering (DMLS) 3D printing. We intend to use this customisable and relatively inexpensive technique to fabricate MNEs which provide improved signal quality, particularly during long-term measurements of dynamic muscle activity.

METHODS: 5x5 needle arrays out of biocompatible stainless-steel (316L) are printed using a DMLS 3D printer (Mlab, Concept Laser GmbH). The arrays are then electropolished in a 50/50 Ethylene Glycol/Glycol Sulfa Ester solution. The printed needles are measured to be 1.6mm in height with a 550µm base diameter. In the next step, the arrays are embedded in silicone, leaving a needle tip of 0.5mm height exposed. And subsequently sterilised. A snap connector is then adhered to the back using silver epoxy. To evaluate the MNEs, they are used to record the biceps brachii muscle during isometric contraction. Prior ethical approval was gotten from the university's research ethics committee. For comparison, wet Ag/AgCl electrodes (Vermed) are also used during these measurements. Skin preparation is performed before electrode placement. The stratum corneum is removed using adhesive tape stripping. Next, the skin is rubbed down with alcohol wipes and finally an electrolyte gel is applied.

Results: The EMG-RMS amplitude during contraction was 0.51mV and SNR was 31.70dB for MNEs. For the wet electrodes the EMG-RMS amplitude and SNR were measured to be 0.41mV and 35.91dB respectively.

Discussion: The fabricated MNEs displayed good signal recording capabilities which compared well to standard wet electrodes. Skin preparation was performed for direct comparison and should not be necessary in the case of MNEs. This will be examined in future. Our fabrication technique is simple and allows for easy customisation of array parameters (e.g. needle height and array size). In future testing, we aim to investigate the performance of MNEs during long-term dynamic activity without prior skin preparation. [1] A. Searle and L. Kirkup (2000); [2] S.H. Roy et al. (2007)

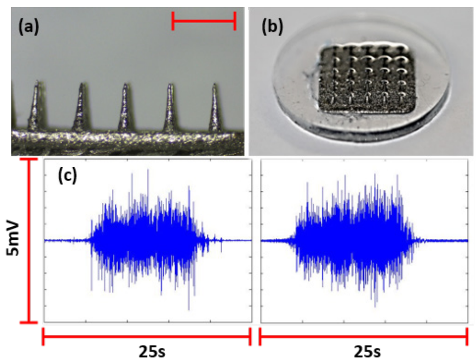

Figure 1: (a) 3D Printed Microneedle Array after Electro-polishing (b) Microneedle Electrode (c) sEMG Measurements from Standard Wet Electrodes and MNEs

O28.4 High-Density Electrodes For Intramuscular Electromyographic Recordings

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BACKGROUND AND AIM: We have previously developed and tested thin-film intramuscular electrodes with 16 detection sites arranged in a linear configuration with 1-mm inter-site distance (Muceli et al 2015). In this we present the development of a more advanced system that features 40 detection sites spaced 0.5 mm apart and arranged on the bottom and top layers of a thin polyimide substrate.

Methods: The thin-film electrode was built using a double-sided microfabrication processes. First, a 5-µm polyimide layer was spun on a silicon wafer; platinum electrode contacts and gold tracks were then sputtered and lift-off structured to form the lower electrode contacts and tracks. Another 5 µm polyimide layer was deposited, followed by the upper electrode gold tracks and platinum contacts, and a 5 µm polyimide layer for insulation. The contacts were then opened by reactive ion etching. To facilitate implantation, a 25-gauge needle was hooked to the electrode. The needle is necessary to introduce the thin-film structure within a muscle and then withdrawn, leaving the electrode inside the muscle for recording. Electrode impedance spectroscopy was performed in the range 0.1 Hz to 100 kHz to characterize the electrical properties of the electrode. The electrode was tested in one subject during 10 s isometric contractions of the tibialis anterior muscle at 10% MVC. Forty channels of EMG signals were recorded in monopolar derivation. Signals were decomposed with the EMGLAB software (Mc Gill et al. 2005). The signal quality was assessed calculating the peak-to-peak amplitude of the motor unit action potentials resulting from the decomposition process and the root mean square of the baseline noise.

Results: Impedance measurements indicated the absence of short-circuits resulting from the manufacturing process despite the small inter-site distance. The mean amplitude of the detected motor unit action potentials was 1.1±0.7 mV while the baseline noise was 40±17 µV across all channels.

Conclusion: We have developed a double-sided intramuscular electrode that provides high-density intramuscular signals with high signal-to-noise ratio.

O28.5 Single-needle multiscanning-EMG

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BACKGROUND AND AIM: Investigation of the motor unit (MU) structure and architecture can be achieved by recording the spatio-temporal variation of the motor unit potential (scanning-MUP) by applying the scanning-EMG technique. A recent advance allows to record multiple scanning-MUPs from a single insertion of the scanning needle by means of decomposing the EMG of one or several auxiliary electrodes. We propose an automatic method to extract multiple scanning-MUPs from a single insertion excluding the use of auxiliary electrodes. This can be achieved in a two-step procedure: decomposing the short EMG segments recorded in each position of the scanning needle; and linking the decomposed MUPs of consecutive recording positions by means of a greedy algorithm.

Methods: Decomposition is performed by means of a hierarchical clustering algorithm that takes into account both waveform and firing pattern information. Each of the tree nodes defines a representative MUP obtained by averaging individual discharges from all the sub-nodes, and the MU firing pattern of the corresponding discharges. The distance between two tree nodes is calculated by combining the distance between their representative MUPs and two penalization factors based on the inter discharge intervals (IDIs) of the firing pattern: the ratio of IDIs below a given threshold; and a function of the minimum IDI penalizing the smallest ones. The use of penalizations precludes from mixing discharges from different MUs. Linkage is performed by means of a single-pass greedy algorithm that takes into account waveform information. Distance between representative MUPs of two consecutive recording positions is calculated in the best-alignment case. The greedy algorithm iteratively performs link exchanges between the pairs of representative MUPs that lead to the maximum decrease of summed-distance. Link exchange stops when the possible exchanges fail to provide further decrease of the summed-distance. In order to allow for arbitrary start and end in the spatial dimension of the scanning-MUPs, a maximum distance between two representative MUPs is allowed in order to create a link, hence to be considered as a part of the same scanning-MUP.

Results: The method is tested both in simulated and real signals.
Results in simulated environment show a high accuracies both in the decomposition (95%) and in the linkage (93%) as well as a small error on the extracted scanning-MUP waveforms. Reconstructed MUPs always include all of the MUs whose territories are traversed by the scanning corridor and many of the closest MUs.
Results in real signals, compared to reference scanning-MUPs obtained by decomposed EMGs recorded from auxiliary electrodes also show a high accuracy and low error in the reconstructed scanning-MUPs.

Conclusions: The proposed method is a promising technique that largely simplifies scanning recordings given that is able to simultaneously extracting several scanning-MUPs with the use of a single needle.

O28.6 Experimental setup for objective evaluation of ultrasound speckle tracking in the human uterus

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Background and aim: Uterine motion plays an important role for the success of embryo implantation. This is especially relevant in the context of assistive reproduction technology. Unfortunately, the lack of tools for quantitative analysis limits our understanding of the uterine activity. Recently, motion analysis by ultrasound (US) speckle tracking has gained attention for assessment of the uterine activity. However, the absence of a ground truth hampers the optimization of this technology. This work proposes the first experimental setup able to generate controlled uterine motion, especially suitable for evaluation and optimization of ultrasound speckle tracking methods.

Methods: A human ex-vivo uterus was submerged in saline immediately after laparoscopic hysterectomy. An electromagnetic actuator generated a controlled, linear displacement of a syringe piston, injecting 3-mL saline through a balloon catheter inserted into the uterine cavity (Fig.1a). Uterine motion was induced with periodic (sinusoidal, 0.05 Hz) inflation and deflation of the uterine cavity. This way, controlled, realistic uterine motion was generated while maintaining the original speckle characteristics. Two needles were inserted in the uterus to realize clear markers of uterine motion. These two markers, along with the driving signal of the actuator, represented the reference for assessing the speckle tracking accuracy. In order to test the value of the proposed setup, the rhythmic uterine motion was assessed by ultrasound speckle tracking. Correlation coefficient (r), mean square error (MSE), and Hausdorff distance (H d), were the adopted objective metrics for assessment of speckle tracking performance. Block-matching by sum of absolute differences (SAD) with three different block sizes was employed as a use case for speckle tracking evaluation. For each US loop acquired, twelve blocks were positioned around each marker (needles) in a way that shadowing was avoided (Fig.1b). The 12 surrounding blocks were simultaneously tracked over time by the 2D speckle tracking method under evaluation. SAD was optimized and compared for its agreement with the references signal. 4-min US imaging was performed with a WS80A ultrasound scanner (Samsung) equipped with a transvaginal V5-9 probe.

Results: The results show the tracking performance of SAD with larger block size (1.724 x 1.724 mm 2) to produce the most accurate tracking of the controlled tissue (speckle) motion ($p < 0.05$).

Conclusions: The realized proposed experimental setup is able to generate controlled uterine tissue motion, providing a realistic ground truth for objective evaluation of US speckle tracking methods and aiding with the choice of the optimal imaging settings for quantitative uterine motion outside pregnancy. speckle tracking methods.

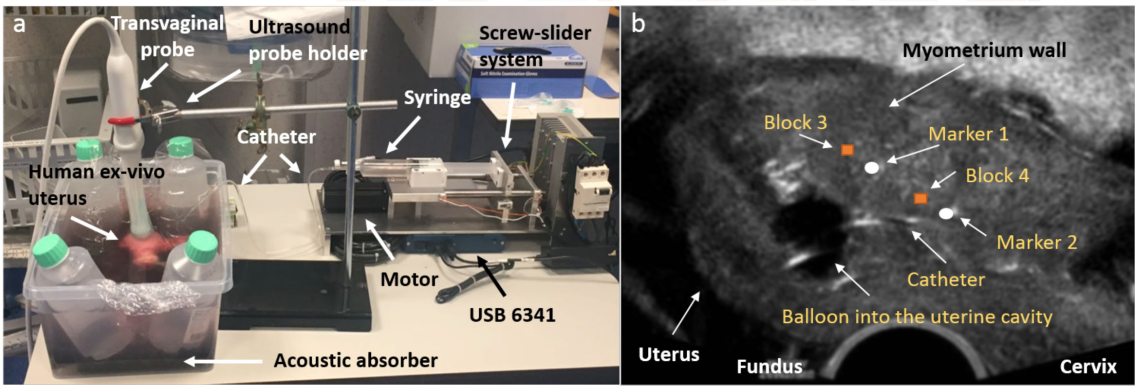

Figure 1: (a) Experimental setup producing simulated rhythmic uterine motion for speckle tracking method validation and (b) ultrasound image of the human ex-vivo uterus with two needle markers (white circles) and two of their surrounding blocks (orange blocks) positioned next to each marker for speckle tracking evaluation.

O29 BACK, NECK & SHOULDER PAIN III - SHOULDER & NECK

O29.1 Fatigue-induced changes in cervical extensors muscles on sensorimotor performance: manifestations in subclinical neck pain group

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Background: Individuals with neck pain (NP) consistently showed impaired level of endurance of their neck muscles. A recent prospective study revealed that endurance of the cervical extensors is a sensitive outcome to predict recovery of office workers with NP at one-year follow-up. To further examine the role of endurance deficiency in natural progress of NP, we examined 1) immediate effects of fatiguing of cervical extensors on changes in sensorimotor performance in individuals with chronic NP, and 2) differences in performance towards the same fatigue task after completing cervical extensors endurance exercise.

Methods: 15 young adults (8 with NP rated 3.6±1.5cm on 10cm VAS [NP group] and 7 age- and gender-matched healthy controls [Healthy group]) underwent sensorimotor performance assessments before and after cervical erector spinae (CES) fatigue task using sustained isometric contraction at 70% of maximal voluntary contraction (MVC). Sensorimotor assessments included 1) head-neck relocation accuracy, 2) maximal velocity and 3) electromyographic activities of the CES and upper trapezius (UT) when performing self-paced active cervical flexion and extension. NP group then completed a 4-week of CES endurance exercise program before reassessment was conducted as described above.

Results: Baseline assessments showed no significant between-group differences in all sensorimotor tests except significantly lower endurance was found in NP group (161.3±56.7s in Healthy group vs 100.3±3.08s in NP group). CES fatigue was verified by the reduction in median frequency value during fatigue task (mean decrease of 23%). Relocation accuracy in flexion and extension improved significantly in NP group after fatigue task at baseline assessment (improved by 2.18±0.35cm and 1.35±0.47cm respectively), however, such positive effect disappeared after exercise program. Maximal flexion and extension velocity showed no significant changes immediately after fatiguing of CES in both groups, and pre- and post-exercise in NP group. During cervical extension, bilateral CES activities were increased after CES fatigue task at baseline assessment (increased by 5.7% MVC at right CES [$p<0.05$] and by 4.9% MVC at left CES [$p>0.05$]), while bilateral UT showed reduced activities (19.4% to 26.5% MVC [$p<0.05$]) in NP group at post-exercise assessment.

Conclusions: Our results indicated that individuals with mild degree of NP displayed a comparable sensorimotor performance to healthy controls at baseline. Interestingly, their head-neck relocation accuracy and selective motor recruitment were facilitated by CES fatigue test. Reduction of UT activity during active neck extension signals muscle activity reorganization associated with endurance exercises in NP group. These findings suggest a potential connection between endurance deficiency and chronicity/recurrence of NP. Further research is recommended to examine the optimal strategies to address problems related to this link identified.

O29.2 Reorganisation Of The Motor Cortex In Individuals With Neck Pain

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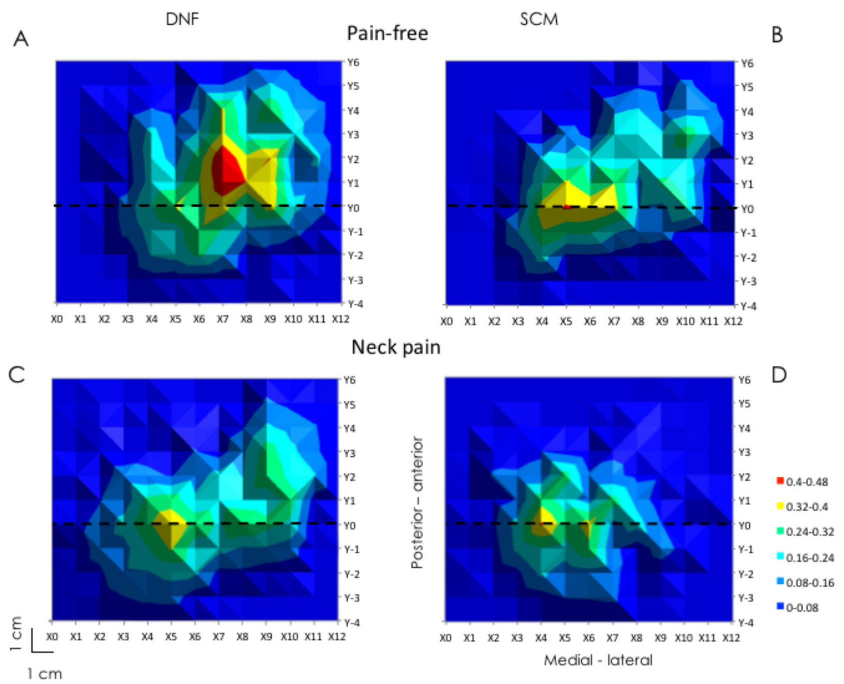
BACKGROUND AND AIM: Neck pain is a common condition and a leading cause of disability that is often associated with changes in sensorimotor control and function. The neural mechanisms that underlie these changes are not yet understood. Changes in the primary motor cortex (M1) representation of specific muscles have been identified in several musculoskeletal pain conditions with some relationship to sensorimotor changes. This has not yet been tested in neck pain. We aimed to evaluate the M1 representation of representative superficial and deep neck flexor muscles in individuals with and without neck pain.

Methods: Electromyography (EMG) of the deep neck flexor muscles (DNF) was recorded with bipolar-electrodes inserted via the nose to the posterior oropharyngeal wall at the level of C2-C3. Surface electrodes recorded sternocleidomastoid (SCM) EMG. Ten pain free controls and ten individuals with neck pain participated. M1 organization was studied using transcranial magnetic stimulation (TMS) applied to a grid over the skull. Amplitude of motor evoked potentials (MEP) were measured and used to generate a three dimensional map of M1 representation of each muscle.

Results: Several differences in M1 representation were identified between groups. Overlap of M1 representation of DNF and that of SCM was less in individuals with neck pain ($p=0.03$). Participants with pain had greater variation in the location of the centre of gravity of the DNF map in the medio-lateral direction ($p=0.02$). SCM and DNF M1 maps we less complex (fewer peaks) in the pain group ($p=0.01$). Individuals with fewer peaks in SCM had greater pain (rho=-0.60, $p< 0.05$) and disability (rho=-0.51, $p=0.02$). Within the pain group, those with shorter distances between location of the centre of gravity of DNF and SCM had greater pain (rho=-0.66, $p=0.04$).

Conclusion: This study provides evidence of differences in organisation of M1 between people with and without neck pain. Notably, some of the differences in M1 organisation contrast reports in other musculoskeletal conditions. For instance, in low back pain, the locations of the M1 maps of back muscles involve greater overlap, whereas in neck pain the overlap between muscle representations was less. Notably, greater variation in M1 representation of neck muscles correlated with pain and disability. This study provides preliminary evidence for a change in neural organisation that may explain the sensorimotor changes identified in this group and could aid the design of interventions.



O29.3 Muscle stiffness is objectively not increased in chronic neck pain

Angela V Dieterich[1], Utku Yavuz[1], Antoine Nordez[2], Deborah Falla[3], Frank Petzke[1]
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Between 27% to 48% of working adults complain of neck pain. Besides pain stiffness is a dominant symptom and the target of therapy. Ultrasound shear wave elastography enables non-invasive, localized measurements of muscle stiffness of superficial and deep neck muscles, thus an extension of the prevalent superficial view on neck muscles. The current study aimed to compare tissue stiffness in the neck region and in subsections typical for the trapezius, splenius capitis, semispinalis capitis and cervicis, and multifidus muscles between females with chronic neck pain and controls during different tasks. Twenty-two females with chronic neck pain and eighteen controls repeated thrice in sitting: graded isometric neck extension at 0, 12 N, 24 N, 36 N and 48 N, and in 30° rotation, a stressful paperwork task, a balance task (sandbag of 1 kg weight balanced on the head); and in supine: relaxation and head lift. Stiffness of the right neck extensor muscles was recorded using shear wave elastography during sustained activation and relaxation, actual force was recorded during graded neck extension. Further, actual and recent pain scores, the Neck Disability Index, the Tampa Scale of Kinesiophobia, and the Depression, Anxiety, Stress Scale were recorded. Stiffness was computer-extracted as average (grand mean) over the neck region and over muscle-specific subsections of the image. Relationships of stiffness to actual force, pain, and psychological variables were examined using Spearman correlation. The grand mean of stiffness over the neck region and muscle-specific stiffness were equal or lower in the pain group, grand mean over all tasks 11.43 kPa for the pain group versus 14.48 kPa for control group, P=0.054. In the pain group stiffness of the semispinalis cervicis muscle was significantly lower during isometric neck extension at 24N and 48N, and during the balancing task, P=0.017-0.032. Correlations of muscle stiffness with actual force were 23%-60% lower in the pain group. Pain duration was negatively correlated with muscle stiffness (?= -0.510- -0.545); fear of movement and stress were positively correlated with muscle stiffness (?= 0.435- 0.529), revealing conflicting relationships. Study results demonstrated an impaired ability to generate appropriate active stiffness of the deep neck extensor muscles in the neck pain group, and conflicting relationships of pain and psychological factors that influence active muscle stiffening in addition to the target force. Findings revealed a discrepancy between objective and perceived neck stiffness, and suggest detailed specifications of dysfunctional neck muscle activation that help to target therapy.

O29.4 The consistency in locating nociceptive stimuli applied to the lumbar region

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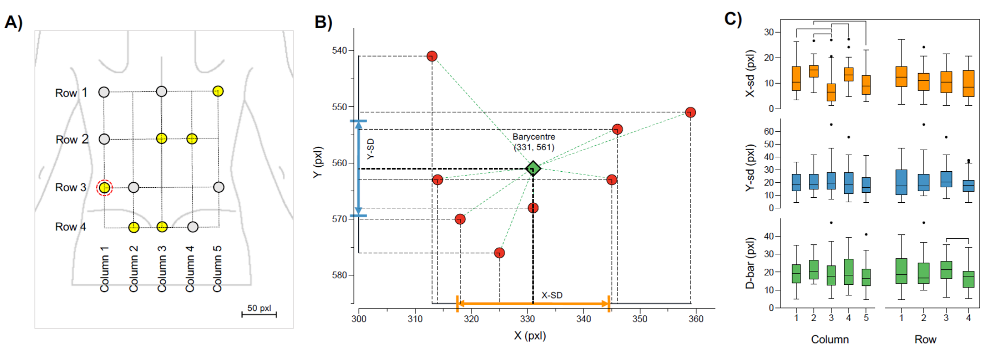
BACKGROUND AND AIM: Digital body charts are used to assess the pain experience in people with acute and chronic pain. Patients are asked to report their pain by shading a human body template on a digital tablet. The aim of this study was to investigate whether healthy volunteers could consistently locate on a digital body chart, nociceptive stimuli induced in the lumbar region.

Methods: Thirty-six healthy volunteers participated in the study. A standardised grid of four rows and five columns was drawn over the participants' lumbar region. Six circular electrodes, connected to a constant current stimulator, were applied at points on the grid: one on the cross between column three and row four, five in the remaining crosses by means of a stratified randomisation procedure (i.e. one electrode for each columns). Additionally, six electrodes not connect to the electrical stimulator were distributed over the remaining crosses (Fig.1A). Volunteers were blinded to the electrode locations. Eight painful electrocutaneous stimuli were randomly delivered for each connected electrode. Participants were instructed to draw where they perceived each painful stimulation using a digital body chart on a tablet (Apple iPad Pro, 12.9, US) with a stylus pen. The body chart was centred on a canvas 768x1024 pixels (pxl), and pain location was defined by X and Y coordinates. For each stimulated electrode, the barycentre was computed for the eight locations reported on the digital body chart. The consistency in reporting the location of each painful stimulation was described using three variables: the standard deviation of the X coordinates (X-sd), the standard deviation of the Y coordinates (Y-sd) and the mean distance from the barycentre (D-bar) (Fig 1B).

Results: The median(IQR) X-sd was 10.3(9.1) pxl, the median(IQR) Y-sd was 18.2(12.9) pxl and the median(IQR) D-bar was 18.3(10.5) pxl. X-sd in column three was significantly lower than in column one, two, and four. No significant difference was found between column and rows for Y-sd. No significant difference was found between column and rows for D-bar, except between row three and four (Fig1C).

Conclusion: The consistency in reporting the location of nociceptive stimuli to the lumbar region in healthy volunteers is higher in the horizontal direction than in the vertical direction. As expected the highest consistency was observed along the midline of the body (i.e. column three) for the horizontal direction. The median variability in locating the nociceptive stimulations on the digital body chart were 2.5 mm for the horizontal direction and 4.5 mm for the vertical direction. Additionally, the D-bar corresponded to 4.5 mm. The consistency in locating the nociceptive stimuli, considering the physical dimension of the digital body chart (i.e. 262x197 mm), appear to be adequate for pain location assessment. The acquired data will serve as a foundation for further investigations in patients with chronic low back pain.



O29.5 The initial effects on shoulder muscle activity of shoulder mobilization with movement during shoulder abduction: a repeated-measures study on patients with pain-limited shoulder elevation

Daniel Cury Ribeiro[1], Gisela Sole[1], Jonathan Shemmell[1], Bill Vicenzino[2]
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BACKGROUND: Shoulder mobilization with movement (MWM) may help to restore optimal control of scapular and shoulder muscles in patients with shoulder pain. This study aimed to explore the immediate post-mobilization effect of MWM on shoulder muscle activity during shoulder abduction.

METHODS: This was a repeated-measures, two-treatment crossover, and participant-blinded randomised trial. Participants Thirty-two patients with pain-limited shoulder elevation were included in the study, and were exposed to two conditions (MWM & sham). Participants attended 2 sessions, at least one day apart to minimize carry-over effects. The order of the experimental conditions was randomized. Instruments We used a motion analysis system (sampling frequency: 120 Hz) to monitor arm movements, and surface electromyography (EMG) to record activity in the upper trapezius, lower trapezius, supraspinatus, infraspinatus, middle deltoid, posterior deltoid, and serratus anterior muscles, following Surface EMG for the Non-Invasive Assessment of Muscles guidelines. EMG data were sampled at 3000 Hz. The motion analysis and EMG equipment were synchronized. Electromyographic recordings were root mean square smoothed using a 50-millisecond average window. EMG recordings were normalized by participant's maximal voluntary isometric contraction. Outcome measures Mean activity levels during shoulder abduction trials were calculated for each muscle at baseline and immediately after each experimental condition. Pain level during shoulder abduction (measured with a visual analogue scale), and shoulder abduction range of movement (measured with a hand-held goniometer) were also recorded at baseline and after each experimental condition. Statistical analysis We used three mixed-effect models for repeated measures analysis of variance for within- and between-condition comparisons, with the following dependent variables: (1) muscle activity at follow-up; (2) pain during shoulder abduction at follow-up; (3) shoulder abduction range of motion at follow-up. Participants were considered as fixed-effect. The order of interventions was considered as a random-effect. Baseline measurements were used as a covariate for between-condition comparisons.

RESULTS: There were no carry-over effects. Lower trapezius and middle deltoid increased muscle activity levels during the concentric phase, while the supraspinatus and serratus anterior muscles increased activity during the eccentric phase (Table 1) following MWM when compared to the sham condition. There was no significant difference in pain levels at follow-up between the two conditions (difference: -0.3, 95%CI: -0.6, 0.1), but significant difference in range of motion at follow-up after the MWM compared to the sham condition (difference: 14˚, 95%CI: 5.1, 23.5).

Table 1. Differences in muscle activity levels (expressed as percentage of maximal voluntary isometric contraction) between sustained glide and sham condition at follow-up.

	Within-condition comparisons			
	MWM		Sham	
	Concentric Phase	Eccentric Phase	Concentric Phase	Eccentric Phase
UT	-9.8 (-21.8 to 2.2)	-5.8 (-12.6 to 0.9)	-10.4 (-22.4 to 1.6)	-0.5 (-7.3 to 6.2)
LT	-16.4 (-30.9 to -1.9)	-5.6 (-13.2 to 1.8)	-2.3 (-16.8 to 12.2)	0.2 (-7.3 to 7.6)
Supra	-12.4 (-27.8 to 3.1)	-9.8 (-17.8 to -1.8)*	-7.8 (-23.4 to 7.5)	-2.1 (-10.2 to 5.8)
Infra	-5.6 (-17.6 to 5.7)	-2.9 (-10.3 to 4.5)	-3.8 (-15.5 to 7.8)	-1.8 (-9.2 to 5.6)
MD	-13.7 (-25.9 to -1.5)	-4.5 (-9.3 to 0.2)	-3.7 (-15.9 to 8.5)	-3.1 (-7.9 to 1.8)
PD	-14.6 (-37.3 to 8.0)	0.8 (-9.3 to 10.8)	4.4 (-18.2 to 27.1)	-4.3 (-14.4 to 5.8)
SA	-8.5 (-17.2 to 0.2)	-7.5 (-12.0 to -3.1)*	-2.9 (-11.6 to 5.8)	-0.06 (-4.5 to 4.3)
	Between-condition comparisons			
	Concentric Phase		Eccentric Phase	
UT	0.5 (-10.9 to 11.8)		5.5 (-0.8 to 11.8)	
LT	14.1 (0.1 to 27.7) *		5.4 (-1.2 to 12.0)	
Supra	6.1 (-5.1 to 17.4)		8.0 (1.6 to 14.5) *	
Infra	3.4 (-6.7 to 13.6)		1.8 (-4.4 to 8.0)	
MD	13.2 (2.6 to 23.8) *		1.9 (-1.9 to 5.9)	
PD	20.9 (-1.3 to 43.2)		-4.4 (-13.2 to 4.4)	
SA	6.3 (-0.5 to 13.2)		7.1 (3.3 to 11.0) *	

* = statistically significant differences. Within-condition comparisons, negative values = higher muscle activity at follow-up than at baseline; Between-condition comparisons, positive values = higher muscle activity during sustained glide (MWM) condition than during the sham condition.

O29.6 Is grip strength a reliable indicator of recovery following upper limb fatigue?

Omid Khaiyat[1], David Hawkes[2], Michael Grant[1], Jessica McMahon[1], Ian Horsley[3]
[1]Liverpool Hope University, [2]University of Liverpool, [3]English Institute of Sport

Introduction: Weak, fatigue susceptible muscles, impact on normal shoulder function. This is particularly pertinent to high level throwing athletes, who can suffer with a range of shoulder injuries. Currently there is little understanding of the nature of shoulder fatigue progression and the mechanisms that can be used to monitor recovery. Power grip activates key shoulder girdle muscles as defined by kinetic chain principles. Recently there is interest within elite sport in the use of grip strength to chart recovery from shoulder fatigue and injury. The aim of this study is to evaluate the relationship between grip strength and the recovery of shoulder girdle muscles from fatigue.

Methods: Twenty healthy participants were recruited. A telemetry system was used for EMG signal acquisition (Noraxon Inc., USA). The activity of 15 shoulder girdle muscles was studied. Muscle fatigue was measured during a shoulder elevation (90o) isometric contraction performed in the scapula plane at 25% of the maximal voluntary contraction. Subjects completed three fatiguing contractions in different testing scenarios: an initial baseline recording (Fat-Baseline); after a shoulder exercise regime which was undertaken until exhaustion (Fat-Exhaustion); and after a 10 minute rest period (Fat-Recovery). Grip strength was also measured in the same three scenarios (Grip-Baseline, Grip-Exhaustion, Grip-Recovery). The median frequency (MDF) was calculated in 1s epochs through the contractions and used as the fatigue index. A repeated measures analysis of variance was used to compare the different fatigue contractions and grip strengths.

Results: Mean Grip-Baseline was 38.0±11.8N, mean Grip-Exhaustion was 34.1±9.1N and mean Grip-Recovery was 37.8±10.5N. Significant differences existed between the testing scenarios with Grip-Exhaustion significantly lower than Grip-Baseline ($p=0.012$) and Grip-Recovery ($p=<0.001$). Significantly greater fatigue was seen in anterior deltoid, middle deltoid, posterior deltoid and supraspinatus in the Fat-Exhaustion contraction as compared to the Fat-Baseline contraction ($p=<0.001$-0.043). Significantly greater fatigue was seen during the Fat-Recovery contraction for the middle trapezius, lower trapezius, serratus anterior and biceps brachii as compared to the Fat-Exhaustion contraction ($p=0.008$-0.038).

Conclusions: Grip strength was significantly lower following exhaustion however it recovered to baseline following a rest period. Conversely, EMG indices of fatigue did not recover. Additional fatigue was seen in the peri-scpaula muscles and elbow flexors which reflects a reorganisation of movement strategy with adaptations occurring to protect fatigued muscles. In conclusion, performance level was restored following the rest period but this is achieved by a reorganisation of movement strategy. Susceptibility to injury therefore still exists if grip strength alone is used as a barometer of return to play.

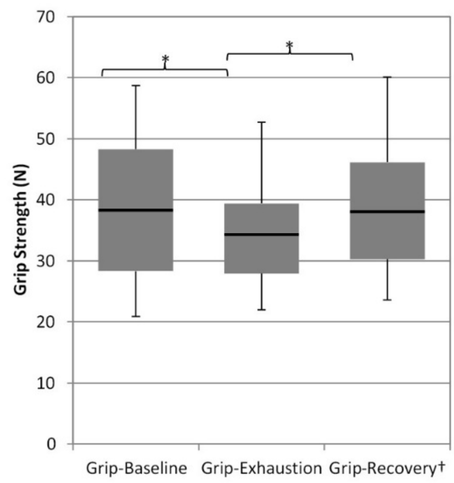


Figure. Box and whiskers plots comparing grip strength in the different testing scenarios. Grey box represents interquartile range; black line mean; error bars minimum and maximum values; * indicated significant differences; † both study groups (SR-G + VMR-G)

POSTER PRESENTATIONS

Saturday, 30th June

1 Poster Session I, Saturday June 30th

1

BIOMECHANICS

PI.1 Intramuscular Pressure of Tibialis Anterior Muscle Reflects in vivo Motor Unit Activity

Filiz Ates, Krista Coleman-Wood, William Litchy, Kenton R Kaufman
Mayo Clinic

BACKGROUND AND AIM: Muscle function depends on motor unit (MU) size and activity. Intramuscular pressure (IMP) is the fluid hydrostatic pressure generated within a muscle and directly reflects the forces generated [1]. Therefore, IMP can be used to evaluate local muscle function. This study was conducted to test the following hypotheses on human tibialis anterior (TA) muscle in vivo: (i) IMP reflects the compound muscle action potential (CMAP) activity. IMP follows the increase in muscle activity imposed by (ii) graded increase of stimulation and (iii) increasing rates of stimulation frequency. (iv) The ankle torque electromechanical delay (EMD) with respect to fine-wire electromyography (fwEMG) is greater than the onset delay of IMP.

METHODS: Twelve young healthy adults (6 males; mean (SD) = 28.1 (5.0) years old with 25.3 (5.9) kg/m2 body mass index) were recruited and provided informed consent. Stimulation of the peroneal nerve provided the (i) CMAP, (ii) seven levels of minimally increasing graded stimuli, and (iii) supramaximal stimuli at frequencies of 2, 5, 10, and 20 Hz. All stimulations were applied twice. Ankle torque, TA IMP, fwEMG, and surface electromyography (sEMG) were measured simultaneously.

RESULTS: The IMP was highly correlated with the applied voltage (ρ=0.96 (0.05)). An increase of the stimulation amplitude was reflected by an increase in the IMP (P<0.0001): The IMP during the CMAP activity was significantly higher than at all other levels. The IMP measured at level 7 was higher than the IMP at level 1 (P=0.007), 2 (p=0.009), and 3 (P=0.026). The IMP at level 6 was higher than the IMP at level 1 (P=0.023) and 2 (P=0.046). Increasing stimulation frequency caused ankle torque (P<0.0001) as well as the IMP (P<0.0001) to increase (Figure): The ankle torque was higher during 20 Hz stimulation compared to 10 Hz (by 50.3%, P<0.0001), 5 Hz (by 66.8%, P<0.0001), and 2 Hz (by 69.8%, P<0.0001). The IMP were higher during 20 Hz stimulation compared to 10 Hz (by 45.0%, P=0.0077), 5 Hz (by 61.1%, P=0.0005), and 2 Hz (by 67.8%, P=0.0002). The ankle torque EMD (median (range) = 53.4 (25.1) ms) was later than the onset of IMP (21.2 (20.0) ms) (P=0.0004) and sEMG (2.9 (8.4) ms) (P<0.0001). Moreover, the onset of sEMG was significantly earlier than the IMP EMD (P=0.0086).

CONCLUSIONS: The hypotheses are confirmed. Our findings indicate that IMP reflects in vivo muscle activities and local muscle mechanical characteristics. The onset of IMP earlier than the torque EMD indicates that IMP represents the local muscle mechanical response. Present findings suggest that IMP can be designed to serve as a minimally invasive tool to evaluate the electromechanical performance of individual muscles. This needs to be further tested with additional specific studies.

REFERENCES [1] Aratow et al. J Appl Physiol. 1993. ACKNOWLEDGEMENTS NIH Grant (R01HD31476) and TUBITAK 2219 programme.

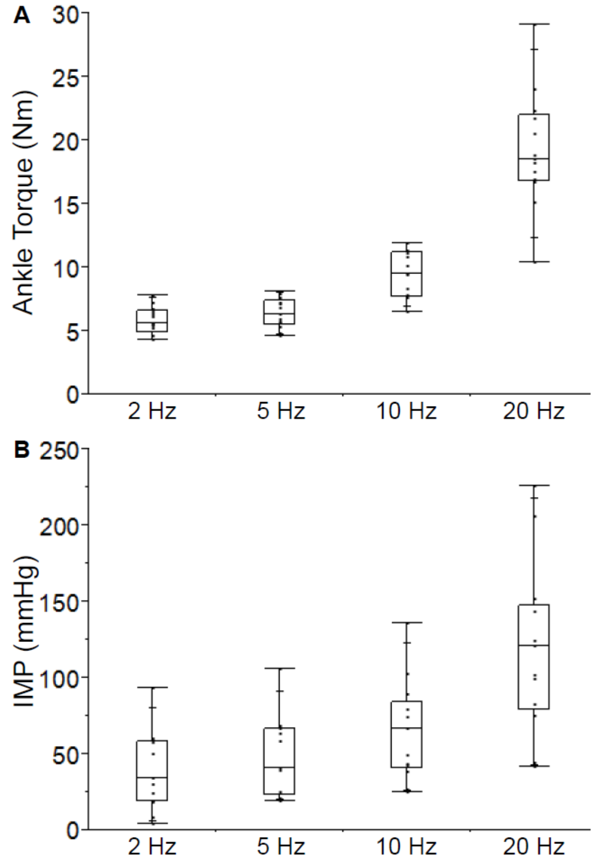


Figure. Box and whisker plot of **A)** the ankle torque and **B)** the intramuscular pressure (IMP) at different stimulation frequency rates.

PI.2 Tracking system of human scapula using sonography: new opportunity to assess scapula diskinesia

Manuel González Sánchez[1], Manuel Trinidad-Fernández[1], Antonio Cuesta-Vargas[2]
[1]University of Málaga, [2]Queensland University Technology, Brisbane, Australia

Background and Aim: A variety of mechanisms that relate neck and shoulder pain to posture are already described in the literature, such as forward head posture, scapular protraction, humeral internal rotation and increased thoracic kyphosis. Scapular protraction is defined as scapular anterior tilting together with scapular internal rotation, however further research is required to determine the validity of this measurement technique in patients with various shoulder conditions, together with the diagnostic accuracy of the test. The invasive methods are very difficult to perform in the clinical practice and the non-invasive methods placed over the skin can cause mistakes in measurements. Aim: The purpose of this study was to validate a new minimally invasive method of tracking internal and external rotation of the scapula using ultrasound imaging combined with the signal provided by a three-dimensional electromagnetic sensor.

METHODS: In vitro and in vivo reliability were verified by an analytical descriptive study of repeated measures. Thirty subjects were recruited for in vivo analysis. The sensor was placed on the ultrasound transducer to 3.5 cm with adhesive tape to avoid interference. An anatomic model of a thorax and scapula was used for in vitro reliability. This anatomic model was immersed in a water container. The scapula was fixed in two positions: 20º and 25º between spinous processes of the vertebrae and the lower angle of the scapula. The accuracy of the scapula rotation using the in vitro model was calculated by correlation between ImageJ®1.4 and MATLAB®2014. The scapula rotation was measured by a two-dimensional cross-correlation algorithm using MATLAB®2014. An experienced professional palpated the scapula and the sixth rib as references. The two positions of the subjects were 0º of shoulder separation and 120º in the frontal plane. The transducer changed position due to movement of the scapula along the ribcage.

RESULTS: The in vitro correlation was r=0.78 (p=0.009). No significant differences in any of the paired repetitions in in vivo measurements (p=0.67-0.34) were found by one-way ANOVA test.
Discussion and conclusions: The findings provide foundations for future work using ultrasound imaging and motion sensors to develop the clinical implications and biomechanics in different types of populations.

PI.3 Tendon and aponeurosis displacement magnitude is different in gastrocnemius lateralis but not medialis during a submaximal isometric contraction

Susann Wolfram[1], Emma Hodson-Tole[2]
[1]University of Bath, [2]Manchester Metropolitan University

BACKGROUND AND AIM: Muscle fibres generate force, which is transferred to bone via aponeuroses and tendons. The amount of force transferred to bone is dependent on the arrangement of fibres within the muscle belly and the stiffness of the muscle's aponeurosis and tendon. Stiffness, a material's ability to resist displacement, has previously been shown to differ between tendon and aponeurosis in some muscles but not others. Therefore, this relationship may be dependent on the muscle and the function it has at the joint it crosses. The purpose of this study was to investigate whether the displacement of tendon and aponeurosis differed between gastrocnemius medialis (GM) and lateralis (GL) during a ramped submaximal isometric contraction and, if present, to specify at which contraction level differences occurred.

METHODS: 18 participants (11 males, age 39.8 ± 9.3 years, height 173.9 ± 8.2, body mass 72.7 ± 11.0) performed ramped isometric plantarflexion contractions to 70% of their maximum voluntary contraction (MVC) level. The muscle bellies and muscle-tendon junctions (MTJ) of GM and GL were imaged using ultrasound. Tendon displacement was determined as proximal displacement of the MTJ, and aponeurosis displacement was determined as proximal displacement of the fascicle attachment point on the deep aponeurosis. Statistical parametric mapping was applied to determine at which contraction levels any displacement differences occurred.

RESULTS: From rest to 70% MVC, GM tendon and aponeurosis total displacement was 15.0 ± 6.5 mm and 11.1 ± 4.2 mm, respectively, while GL tendon and aponeurosis total displacement was 11.2 ± 5.3 mm and 32.2 ± 24.4 mm, respectively. There was no difference between total tendon and aponeurosis displacement in GM ($p > 0.05$) but in GL tendon displacement was significantly smaller than aponeurosis displacement from 8% to 70% MVC ($p < 0.001$). There was also a significant difference in displacement between the GM and GL tendon from 41.8% to 70% MVC and between the GM and GL aponeurosis from 33.2% to 70% MVC (both $p < 0.001$).

CONCLUSIONS: This study showed that the displacement of tendon and aponeurosis differs during isometric submaximal contractions but this difference is dependent on the muscle. Displacement of tendon and aponeurosis was similar in GM but differed significantly in GL from very low contraction levels onwards. This may indicate differences in the mechanical properties of these tissues in longitudinal direction and, consequently, the way force is transferred from the muscle belly to bone. Displacement differences between the tendons of GM and GL and between the aponeuroses of GM and GL occurred at similar contraction levels suggesting some interaction between both gastrocnemii

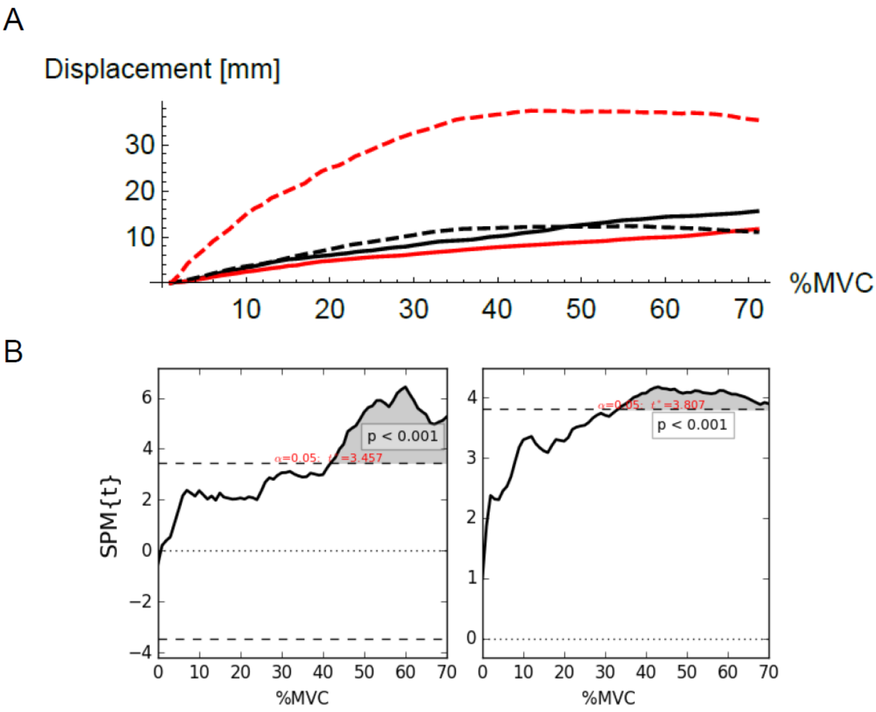


Figure 1. (A) Mean displacement of the tendon (solid) and aponeurosis (dashed) from rest to 70% MVC for GM (black) and GL (red). (B) Results from a t-test using one-dimensional statistical parametric mapping comparing tendon displacement between GM and GL (left) and aponeurosis displacement between GM and GL (right). Differences in displacement are indicated with grey shaded areas.

PI.4 Ultrasound-based strain mapping for quantitative characterization of uterine activity outside pregnancy

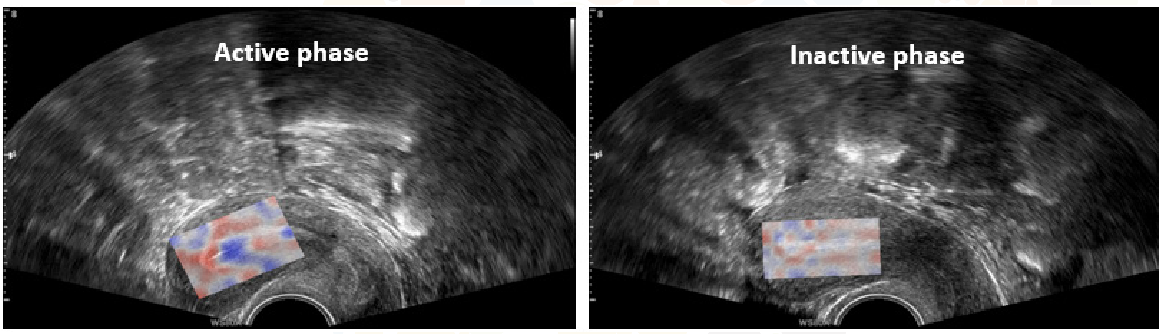
Yizhou Huang, Celine Blank, Federica Sammali, Nienke P Kuijsters, Benedictus C Schoot, Massimo Mischi
Eindhoven University of Technology

Introduction: Uterine peristalsis (UP) plays a relevant role in fertilization. For instance, failure of in-vitro fertilization (70%) can be possibly ascribed to uterine peristaltic movement expelling the transferred embryo from the uterine cavity. An objective and non-invasive characterization of UP can therefore provide an important contribution to many clinical procedures. In this study, strain mapping based on optical flow is applied on two-dimensional (2D) transvaginal ultrasound (TVUS) videos to quantify UP outside pregnancy.

Methods: Eight healthy women, with a natural regular cycle, underwent 4-minute TVUS during active (before ovulation) and inactive (late luteal) phases of the menstrual cycle. Regions of interest (ROIs) were chosen to include the junctional zone close to the fundus. Strain mapping based on optical flow was applied to calculate and visualize strain variations in the ROIs. We considered contraction as negative strain and relaxation as positive strain. The obtained strain maps were rendered with suitable color maps; red color for relaxation and blue color for contraction. Three features, standard deviation, mean frequency and unnormalized first statistical moment were extracted from the strain results to characterize the UP in each phase. Statistical analysis based on Wilcoxon rank sum test were applied on these features to evaluate the differences between the two phases.

RESULTS: In each recording, 2D strain maps were generated in the longitudinal and transversal directions of the uterus. The figure shows an example of strain map in transversal direction for both active and inactive phases. We can clearly visualize the variations in strain around the junctional zone, revealing the propagation of the peristatic movement. From the statistical analysis, we were able to detect a significant difference ($p<0.05$) for each feature between the two phases.

CONCLUSION and Discussion: The obtained results suggest the feasibility of accurate strain mapping in the uterus outside pregnancy and the possibility to classify the UP for different phases of the menstrual cycle. Future work will focus on extending the dataset and the number of evaluated phases. Extension to three-dimensional strain analysis will also be considered to provide more accurate results that are robust to out of plane motion.



PI.5 The effects of age and sex on gait muscle activation and activation variability: Unique muscle recruitment at the stance-to-swing phase for aging females

Christopher Bailey[1], Massimiliano Pau[2], Maria Penna[1], Julie Côté[1]
[1]McGill University, [2]University of Cagliari

BACKGROUND AND AIM: Aging leads to poorer control and slowing of the neuromuscular system that may coincide with changes in gait muscle activation. However, these age-related effects on activation may be unique for each sex, and the rate of change with age is unclear. Accordingly, the objectives of this study were to determine if age-related changes in gait muscle activation are different in males and females, and to estimate the rate of change with age.

METHODS: Adults aged 20-82 y (N = 93, 55 females, 38 males) completed six gait trials, walking at their preferred speed over a 10 m platform. The muscle activation of the rectus femoris (RF), tibialis anterior (TA), and gastrocnemius lateralis (GL) were measured using wireless surface bipolar electromyographic (EMG) sensors, and markers on the foot and shank were used to identify heel strikes for gait cycle identifications. These EMG signals were later filtered and linear enveloped to calculate the root mean squares (RMS) and coefficients of variation (CV) for several phases of gait. Each RMS value was normalized to the peak value of the full gait cycle, the RMS and CV values were averaged across trials for each participant, and the mean RMS and CV were calculated over the full gait cycle and for several of its phases. Mixed effect models were conducted on RMS and CV to test for age, sex, muscle, and interaction effects, covarying for the influences of gait speed and stride length.

RESULTS: A significant Age x Sex x Muscle interaction on RMS at the stance-to-swing phase was found ($p = .048$); post-hoc regression analyses revealed that each decade of age was associated with 2.4% lower TA RMS ($\beta = -.24$, $p = .001$) and 1.4% lower GL RMS ($\beta = -.14$, $p = .031$), only in females. Significant Age x Muscle interactions on RMS were found at the terminal-swing, loading, and mid-stance phases ($ps < .05$), where each decade of age was associated with 1.5-5.1% higher GL RMS ($\beta = .15$-$.51$, $ps < .05$). Significant Age x Muscle interactions were also found on CV at the stance-to-swing, and terminal swing phases ($ps < .05$), generally showing higher CV with higher age.

CONCLUSION: For females only, the TA and GL appeared to be recruited less during the stance-to-swing phase with higher age, indicating a potential female-specific mechanism of ankle instability during the transition from double- to single-leg support. The sex-independent associations of age with higher GL activation, and muscle activation variability in multiple phases of gait, suggest that aging alters neuromuscular control in a manner that could impact gait instability and fall risk in both genders, beyond the influences of gait speed and stride length.

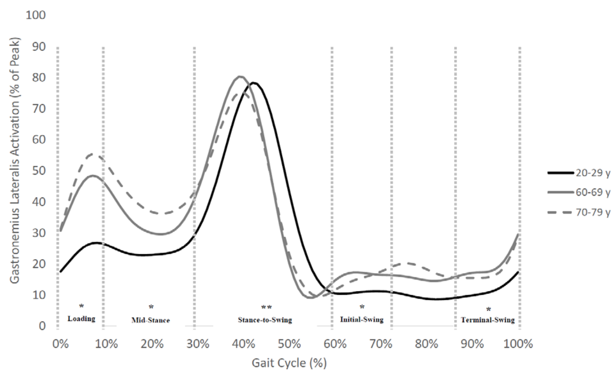


Figure 1. Mean gastrocnemius lateralis activation of participants during the gait cycle. To visualize age effects, mean curves were calculated for adults aged 20-29 y (solid black line), 60-69 y (dashed dark grey line), and 70-79 y (dotted light grey line). Vertical grey lines identify specific phases, and significant age effects (*) and age effects for females only (**) are shown.

PI.6 Biomechanics of a giving way episode in an individual with chronic ankle instability: a case report

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BACKGROUND AND AIM: Individuals with chronic ankle instability frequently experience episodes of giving way of the ankle joint. The biomechanics of the mechanisms of lateral ankle sprain injuries has been well documented. In contrast, the biomechanical characteristics of episodes of giving way of the ankle joint have yet to be reported in the published literature. This study provides the first-ever, biomechanical description of an accidental giving way episode of the ankle joint incurred by an individual with chronic ankle instability whilst performing an agility T-Test in a university sports hall.

METHODS: Five inertial measurement units, as well as a high-speed camera captured the athlete's (age = 22 years; height = 1.78 m; body mass = 97 kg) lower limb biomechanics throughout the completion of a maximum effort agility T-Test, including the accidental giving way episode. The accidental giving way episode was analysed and compared to a previous maximum effort trial during which no giving way episode occurred.

RESULTS: Video analysis identified nine key events associated with the giving way mechanism. Analysis of the data recorded by the inertial measurement units illustrate that the giving way episode was characterized by plantar flexion of the ankle joint, as well as internal rotation and adduction of the ankle-foot complex, with peak rotational velocities reaching 797°/s, 1087.6 °/s and 1733.7°/s, respectively.

CONCLUSION: This biomechanical description provides a unique insight into the characteristic features of giving way episodes experienced by individuals with chronic ankle instability. The findings can be utilized in the development of rehabilitation programmes and design of protective equipment for individuals with chronic ankle instability.

PI.7 Forearm muscle activity and wrist kinematics during dynamic wrist movements with sudden perturbations

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Background and Aim: Sudden perturbations to the distal upper extremity are routine during daily activities. Perturbation protocols can provide insight into neuromuscular control as well as joint stability and injury risk. Wrist perturbations with known timing results in greater forearm muscle activity prior to a perturbation while unknown perturbations have greater reflex responses (Holmes and Keir 2012). This work evaluated muscle responses from a static posture. The purpose of this study was to evaluate changes in wrist stiffness, forearm muscle recruitment and kinematics during perturbtations delivered to the wrist joint while performing a dynamic wrist tracking task.

METHODS: Eight right hand dominant males participated. Muscle activity was measured from seven forearm muscles using surface electromyography (EMG) (Bortec Biomedical Ltd, Calgary, Canada): flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), extensor digitorum (ED), and brachioradialis (BR). Participants were seated with their forearm placed in a robotic device (WristBot, Genoa, Italy) that allows for wrist movement in 3dof. Participants performed 15 repetitions of a wrist flexion/extension task, while tracking a cursor on a computer screen (±40° of wrist flexion/extension at 0.25 Hz). During the repetitions, a 2 Nm perturbation caused either radial or ulnar deviation of the wrist, during flexion or extension, and with known or unknown timing. EMG was linear enveloped at 3 Hz and normalized to muscle specific maximum voluntary exertions (%MVE). EMG and the robotic device were synchronized and perturbation onset was determined. Peak EMG was examined during three-time periods: pre-perturbation (pre-100ms and pre-15ms) and post-perturbation (reflex).

RESULTS: Peak muscle activity for ECU had a significant knowledge*time interaction ($p < 0.05$). Activity during the pre-100ms time period was significantly less than both the pre-15ms and reflex time periods. ECU was significantly greater during known timing compared to unknown timing during the pre-100ms time period (Known: 27.84 ± 8.8% MVE; Unknown: 17.70 ± 8.0% MVE, $p < 0.05$). There was no significant difference between known and unknown timing for the pre-15ms or reflex periods. There was a significant main effect of time for peak muscle activity across all muscles, except BR ($p < 0.05$).

CONCLUSION: Increased peak muscle activity during known timing compared to unknown timing suggests that participants may attempt to increase joint stiffness in anticipation of the perturbation. However, known and unknown timing showed similar peak muscle activity during the reflex period, indicating a similar response post perturbation. Next steps include assessment of co-contraction indices and wrist kinematics (tracking accuracy) which will shed light on joint stiffness levels and performance during various conditions.

PI.8 Effect of bad posture on the standing balance?

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BACKGROUND AND AIM: Bad posture is a well-known problem in children and adolescent, which has a negative effect in adulthood. It can be assumed that due to bad posture, changes in the body position cause changes in standing balance. The objective of the study is to determine the influence of bad posture on the standing balance of school-aged children based on independent time-distance and frequency based foot centre of pressure parameters.

METHODS: Subjects included 113 children of neutral (age: 11.3±1.2 years; body weight: 48.5±14.88 kg; body height 153.3±14.56 cm) and 58 children of bad posture (age: 11.4±1.52 years; body weight: 44.8±11.28 kg; body height 157.0±10.66 cm). 17 parameters (95% confidence ellipse axis ratio; 95% confidence ellipse area; Path length; Max velocity; AP(anterior-posterior)-ML(medio-lateral) range ratio; Load distritbution difference (LDD) between legs; Largest amplitude (LA) in AP direction; Largest amplitude (LA) in ML direction; Maximum deviation in anterior (A max dev) direction; Maximum deviation in posterior (P max dev) direction; Mean power frequency (MPF) in AP direction; Mean power frequency (MPF) in ML direction; Spectral power ratio between AP and ML direction (SPR); Frequency power ratios between low and medium frequency band (LMR) in AP direction; Frequency power ratios between low and medium frequency band (LMR) in ML direction; Frequency power ratios between medium and high frequency band (MHR) in AP direction; Frequency power ratios between medium and high frequency band (MHR) in ML direction) were derived from the motion of the centre of pressure on a platform equipped with pressure sensors, on which the subjects were standing for 60 seconds with both feet and open eyes.

RESULTS: When comparing the two groups, load distribution difference between the legs ($p=0.025$) and the medium-high frequency band power ratio in the medio-lateral direction ($p=0.001$) showed a significant difference out of the 17 parameters. However, the other 15 parameters did not show any significant difference.

CONCLUSIONS: The effects of altered posture are continuously corrected by the central nervous system. The asymmetric load between the two sides may further degrade muscular imbalance, so correcting it is an important task of physiotherapy.

ACKNOWLEDGEMENT: This work was supported by the Hungarian Scientific Research Fund OTKA [grant number K115894].

PI.9 Effect of Joint Angle on Electromyography and Near Infra-red Spectroscopy during Fatiguing Contractions of the Elbow Flexors in Men and Women

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BACKGROUND/AIM: Understanding joint angle and fatigue development may improve protocols for upper limb movement, particularly ergonomic designs where static, upper limb work is common. This study examined the effect of elbow joint angle on sustained maximum voluntary contractions (MVC) during fatigue using surface electromyography (EMG) and near infrared spectroscopy (NIRS).

METHODS: Sixteen young adults (8 males, age= 22.0 ± 1.9 years and 8 females, age= 23.1 ± 1.6 years) volunteered to participate in this research study). Peak torque, surface EMG and NIRS data were recorded at three joint angles (60º, 90º and 120º) during isometric (MVC) elbow flexion using an isokinetic dynamometer. A fatiguing contraction requiring participants to hold 50% of their MVC at each angle was also completed. Torque, median frequency (MF) and tissue oxygenation index (TOI) were compared across the three angles during the MVC and during the fatiguing contraction (start, mid and end).

RESULTS: While males produced higher (absolute) peak torque than females ($p< 0.001$), there was no statistically significant difference in isometric torque across joint angle. Females had a significantly longer time to fatigue than males ($p<0.001$), however there were no significant effect was found between joint angle and time to fatigue in either males or females. During the fatiguing contractions, the MF decreased significantly over time across all angles and there was no difference between the MF of males and females ($p=0.20$). Male data showed a decrease in MF from start to end of the fatiguing contraction, however at 120 º females exhibited a significant decrease in MF throughout the contraction (start, mid and end). The female participants exhibited a significant difference in torque in the fatiguing contraction at 120º compared to 60º ($p=0.029$) and 90º ($p=0.015$) towards the end of the contraction (mid and end). NIRS data showed a significant decrease in TOI across time ($p<0.001$) for both males and females. No differences were detected in TOI across joint angle in females, however male participants displayed a TOI at 120º that was significantly higher than 60º ($p=0.048$) and 90º ($p=0.040$) during the latter part of the fatiguing contraction.

CONCLUSIONS: During isometric MVC, peak torque and time to fatigue were not affected by joint angle in either males or females. During fatigue MF and TOI were affected by joint angle differently in males and female suggesting gender differences. Finally, results showed that peak torque, EMG and NIRS parameters provide complementary information. It is important to consider motor unit recruitment and hemodynamics during static upper limb contractions with respect to fatigue development. Future work examining greater range of joint angle and contraction intensity with participants from industries that require prolonged static upper limb work will help to obtain greater insight regarding the impact of fatigue and help to improve work protocols.

PI.10 Effect of automobile tire changing work height on upper body muscle activation

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Background and AIM: In the United States in 2011, 3.9 of 100 employees in the automotive repair industry had a nonfatal workplace accident or illness associated with daily activities. This is greater than other high-risk occupations in industries such as mining and chemical production (2.3 and 2.4 per 100 employees respectively) [1]. In Canada vehicles have tires changed twice per year. Mechanics use a car hoist to raise the car during this task. However, there are no guidelines or recommendations for car hoist height during tire changing and other automobile repair tasks. The purpose of the study was to identify significant differenc in upper body muscle activation during a tire changing task at three work heights.

Methods: Nine participants changed six automobile tires at three working heights (total = 18 tire changes). The working heights were low (bottom of tire two inches from floor), mid (tire hub at height of iliac crest), and high (tire hub at height of the first rib). Surface Electromyography (EMG) was collected bilaterally (Bortec AMT-8, Bortec Biomedical, Calgary, AB) from the flexor digitiorum superficialis, biceps brachii, anterior deltoid, and erector spinae (longissimus). EMG was collected for each component of the tire changing task. Participants used an impact wrench to loosen and tighten lug nuts. EMG data was bandpass filtered (20-450Hz), notch filtered (59-61Hz), lowpass filtered (cutoff = 1 Hz), and then normalized to the highest RMS value of three MVC's for each muscle. Freidman's ANOVA and post hoc tests using Bonferroni correction between heights, and muscles at each height, were computed using R version 3.3.1.

RESULTS: There was significant difference in normalized maximum RMS (% MVC) between high (median = 27.9) and low (median = 29.9) heights (difference = 69.5), and mid (median = 27.4) and low heights (difference = 101.5), (X^2=21.4,$p<0.05$). There was significant difference in left anterior deltoid maximum normalized RMS between high (median = 22.8) and mid (median = 27.4) heights (difference = 54), and mid (median = 27.4) and low (median = 29.9) heights (difference = 78), (X^2=14.8,$p<0.05$); right deltoid maximum normalized RMS between high (median = 27.4) and mid (median = 16.3) heights (difference = 117), and high and low (median = 18.5) heights (difference = 72), (X^2=35.2,$p<0.05$); left biceps maximum normalized RMS between high (median = 22.8) and low (median = 26.2) heights (difference = 149), and mid (median = 26.2) and low heights (difference = 106), (X^2=54.5,$p<0.05$).

CONCLUSION: Findings indicate significant statistical differences in maximum muscle activity at different working heights, and between muscles at different working heights. Further research is needed to recommend working heights that may reduce muscle activity during automobile repair tasks.

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MODELLING, SIGNAL PROCESSING & SENSING

PI.11 Characterizing Human Muscle Postactivation Potentiation by MMG and Force

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AIM: Postactivation potentiation (PAP) has been shown to improve muscle speed and power as well as offset fatigue, which could be advantageous to athletes. PAP is believed to render actin-myosin interactions more sensitive to the Ca2+ released from the sarcoplasmic reticulum, especially at low myoplasmic levels, such as occurs in twitch (Sale, 2002). The aim of this study was to investigate both the Mechanomyography (MMG) and the force response of the muscle to determine the extent that modelled elements contribute to PAP in the human biceps brachii muscle.

METHODS: Twelve participants, 8 males and 4 females volunteered for this study. The biceps brachii was maximally electrically stimulated and after a sustained 10 second, 100% maximum voluntary isometric contraction, was stimulated again to determine the potentiation response. The two responses measured were the MMG, using an accelerometer at the muscle belly, and the force, using a loadcell at the wrist. Muscle tension can be represented by a spring, a contractile element and a viscous damper, when considering a twitch as a second-order critically damped response (Winter, 1976). MMG, when measured using an accelerometer, can be used to estimate the lateral displacement of the muscle which exhibits second-order underdamped dynamics. The parameters for both responses were compared before and after potentiation.

RESULTS: Both the force in the longitudinal direction and the MMG amplitude in the lateral direction increased post-PAP (50.8% and 10.4%), see table 1. Following potentiation there was a decrease in the stiffness for both force and MMG displacement (2.29 and 1.14 N/m). The natural frequency of the muscle vibration did not show any deviation.

CONCLUSION: A reduction in stiffness allows for increased displacement during muscle vibration (Orizio, 1989), as was found in this MMG response. The result also showed a decrease in the stiffness in both the lateral and longitudinal directions. The change in muscle stiffness alone could not account for the increase in muscle force after potentiation. It has been previously stated that changes in MMG may reflect modifications to the amount of Ca2+ released by the sarcoplasmatic reticulum for fatigued muscles (Orizio, 1999). From these muscle models the element most likely to contribute to an increase in force is the contractile element, probably as a result of the increased sensitivity to Ca2+. In conclusion this study uses muscle models to conclude that the increase in muscle force following PAP is as a result of gains in the contractile element, which is reflected in both the lateral and longitudinal responses of the muscle to a twitch.

Table 1: PAP response results

	Pre-PAP	Post-PAP	Delta
Force (N)	**13.62**	**20.54**	**50.8%**
Stiffness (N/m)	22.16	19.87	-2.29
Damping (Ns/m)	2.53	2.41	-0.12
MMG Displacement (mm)	**1.54**	**1.70**	**10.4%**
Stiffness (N/m)	166.19	164.78	-1.41
Damping (Ns/m)	0.27	0.31	0.04

PI.12 Use of the variance ratio to facilitate validation of motor unit discharge rates in the flexor carpi radialis (FCR) obtained by decomposition of the surface electromyographic signal

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BACKGROUND AND AIM: Several methods have been proposed to validate motor unit discharge rates. McManus et al. (2017) spike trigger averaged (STA) the surface electromyographic (sEMG) signal, using the discharge times identified by the Delsys electromyographic (dEMG) Analysis software (Version 1.1, Delsys, Inc., Boston, MA). High correlations between the extracted motor unit potential (MUP) templates and those obtained by dEMG, were reported for isometric contractions between 20 and 30% MVC.

METHODS: This study extended the autologous STA technique for the flexor carpi radialis (FCR) during isometric wrist flexion at 60% of maximum voluntary contraction (MVC). The probability of superpositions and/or misidentifications is greater at 60% than at 20-30% MVC. A secondary criterion based on the variance ratio (VR) was therefore used. The VR ranges from 0 to 1; if all waveforms overlay perfectly, the VR is 0. Forty subjects completed 3 isometric wrist flexions (60% MVC) on each of the four test sessions. A 5-pin electrode (dEMG System, Delsys, Inc., Boston, MA) placed on the FCR resulted in 4 channels of sEMG activity. The signal-to-noise ratio (SNR) was calculated from a 25 ms epoch containing each MUP.

RESULTS: As might be expected there was a significant negative correlation (-0.63, $p<0.05$) between VR and SNR. When a minimum VR of 0.50 was used to select each channel, only 18 MUP trains (MUPTs) could be extracted across all trials. Increasing the cut-off to 0.73, resulted in a total of 263 MUPTs. In both cases, data would be missing for a majority of the subjects.

CONCLUSIONS: If, however, single channel techniques could be used to externally validate MUPTs, a VR of 0.73 would yield at least two MUPTs per subject on any given day. Depending on the nature of the variability, a VR of 0.85 could be tolerated, yielding at least four MUPTs per subject on any given day. The VR can facilitate the identification of MUPTs by supplementing analysis criteria with greater detail on the variability in the signal.

PI.13 Static Nonlinear Transformation of Excitation Model Input as an Alternative to Feedback Control in EMG-Force Models

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BACKGROUND AND AIM: When modeling EMG and force generation, researchers face the problem of ensuring that the simulated muscle force equals the desired target force. Often, this problem is solved by introducing a feedback control loop that continuously adjusts the excitation model input based on the time course of the force tracking error. While there is certainly a feedback element in physiological force control, it appears questionable whether the proposed feedback controllers correctly reproduce the behavior of the underlying physiological controller. Accordingly, previous authors did not introduce these controllers to model physiological force control, but rather to solve the practical problem of tracking a desired target force with their simulated model. In this contribution, we propose the use of a static nonlinear transformation of the excitation model input as an attractive alternative to feedback control in EMG-force models during non-fatiguing contractions.

METHODS: The model under analysis comprises motor unit recruitment, rate coding, and force twitch generation. Analytical inspection of the resulting force generation capabilities of all motor units at different excitation levels yields the mean generated force at each excitation level. This static nonlinear relationship can then be used as a nonlinear input transformation to ensure that the generated force output equals the target force level, without requiring a dynamic feedback loop.

RESULTS: Input-output force consistency is achieved in the mean, without the necessity to include a feedback loop in the simulation. Moreover, the introduction of this input nonlinearity implicates adjustments to the motor unit recruitment and rate coding characteristics of the model. These adjustments reproduce physiological characteristics observed experimentally, without modeling them explicitly.

CONCLUSIONS: The proposed nonlinear transformation of the input excitation represents an attractive alternative to the commonly used PID force feedback control algorithm. It entails useful implicit modifications to the assumed model of motor unit recruitment and rate coding.

PI.14 Variability of hand motions quantified using EMG root mean square and mean frequency

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BACKGROUND AND AIM: Classification of hand motions is a valuable step for controlling many degrees-of-freedom of a prosthesis. Although high true positive rate has been obtained with acute experiment, performance has shown to decay over time due to changes in the characteristics of the electromyography (EMG) signals causing variability in the performed motions. Whether this is caused by human inconsistency in performing movement or the variability in motor control remains an open question. In this study, we aim to investigate whether different hand motions exhibit similar degree of variability.

METHODS: Sixteen subjects (six transradial amputees and ten able-bodied) participated in the study. EMG signals were recorded for 11 hand motions: Hand Open (HO), Hand Close (HC), Wrist Flexion (WF), Wrist Extension (WE), Supination (SU), Pronation (PR), Side Grip (SG), Fine Grip (FG), Agree (AG), Pointer (PO), and Rest (RT). Six channels surface EMG were recorded for seven consecutive days. For each motion, a single EMG channel was associated and analysed. The condition was that the selected channel must have been active during that motion for all seven days. Three seconds of steady state data was extracted to evaluate mean frequency (MNF) and root mean square (RMS). Coefficient of variance (CoV) was evaluated for each subject per motion for the seven days.

RESULTS: Friedmans test showed a statistically significant difference between motions for RMS and MNF ($P \leq 0.001$) implying that some motions have higher variabilities than others. For example WF (CoV = 12.8 %) had maximum variability among active motions significantly higher ($P<0.01$) than HO and WE (Table 1). Nevertheless, baseline variability was the most prominent. Table: CoV (%) for all motions averaged across all seven days. [Table here]

CONCLUSION: We have shown that a CoV of up to 13% can be observed in EMG amplitude and up to 38% in MNF. Furthermore the degree of variability is motion dependent and probably subject dependent, encouraging a more patient specific design. The results may explain degradation of performance overtime possibly due to handcrafted temporal and spectral features, which are affected by the EMG characteristics and traditional machine learning algorithms are not able to adapt to these changes.

Table: CoV (%) for all motions averaged across all seven days.

	HO	HC	WF	WE	SU	PR	SG	FG	AG	PO	RT
MNF	6.8	8.5	12.8	7.7	10.2	8.2	11.1	8.6	11.7	11.4	16.3
RMS	36.5	32.0	36.5	30.9	35.1	33.4	32.7	35.2	37.5	33.8	42.8

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PI.15 Automatic Window Selection for Quantifying Neuromuscular Jiggle

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BACKGROUND AND AIM: The variability in the shape of the motor unit potential (MUP) at repeated discharges is known as a useful feature in the diagnosis of neuromuscular disease. Stålberg and Sonoo defined the term jiggle for this shape variability and proposed two parameters for quantification: the normalized value of consecutive amplitude differences (CAD) and the cross-correlational coefficient of the consecutive discharges (CCC) [1]. To minimize the influence of noise in the calculation of CAD and CCC, a 5 ms-long analysis window centered in the maximum peak is used. This window is perfectly suitable for estimating jiggle in MUP traces where the values of jiggle are very low. When the amount of jiggle is higher, as is the case with ALS and other neurogenic diseases, some of the MUP discharges may have two or more separate peaks and/or satellite potentials caused by reinnervation of motor units. In these cases, a 5 ms-long window fails to cover all parts of the wave with shape variation and the estimation of jiggle is poor.

METHODS: We propose a new method based on window selection (WSM) that tries to determine the complete length of the MUP wave correctly and uses it for the CAD and CCC calculation. A Butterworth filter is used previously to eliminate baseline fluctuations without considerable distortion of the MUP wave shape. Then, a threshold level is established at 5% of the maximum amplitude of the filtered MUP. Only the samples above this threshold are used for the calculation of CAD and CCC parameters. The new method was compared to Stålberg's method, using real MUP traces taken from deltoid, triceps brachia and tibialis anterior muscles from controls and ALS patients. 89 traces with high jiggle values (jiggle case) were taken from ALS muscles and 72 traces with very low jiggle values (no jiggle case) were taken from normal muscles. The gold standard (GS) CAD and CCC parameter values were obtained by manually selecting the window prior to CAD and CCC calculation. Paired t-tests were performed with a significance level set to 0.05.

RESULTS: Results are given in Table 1.For the jiggle case and the CAD parameter, there were significant differences between results from Stålberg's and the GS, but not between GS and WSM. For this parameter, no significant differences were found in the no jiggle case, nor for the CCC in either case of jiggle.

CONCLUSIONS: The proposed method provides better results for the jiggle case that the conventional approach. This improvement can be related to the use of the complete length of the MUP wave for the jiggle estimation. The new method is, therefore, more convenient in the assessment of jiggle for diagnosis or monitoring of neuromuscular diseases.

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		CAD	CCC
No jiggle	**GS**	0.044 ± 0.06	0.998 ± 0.002
	Stalberg's	0.040 ± 0.05	0.998 ± 0.002
	WSM	0.040 ± 0.05	0.998 ± 0.002
Jiggle	**GS**	0.246 ± 0.17	0.954 ± 0.046
	Stalberg's	0.213 ± 0.16 *	0.962 ± 0.043
	WSM	0.239 ± 0.16	0.958 ± 0.042

Table1: CAD and CCC values calculated by three different methods for the MUPs with jiggle and no jiggle. (*: $p<0.05$, GS vs Stalberg's)

PI.16 On the accuracy of single motor unit firing detection from high-density surface electromyograms

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BACKGROUND AND AIM: In the last decade, techniques for decomposition of high-density surface electromyograms (hdEMG) into contributions of individual motor units (MUs) have been developed. Extensive effort has been made to validate them and various validation techniques have been proposed. Among them, Pulse-to-Noise Ratio (PNR) [1] assesses identification accuracy for each individual MU and, compared to two source validation, reduces experimental costs. It is, however, an asymptotic measure, requiring several tens of MU firings to efficiently estimate the accuracy of MU identification. In this study, we analysed the ability of PNR metric to assess the accuracy of individual MU firing identification.

METHODS: We used an array of 5x13 surface electrodes to record hdEMG by from the dominant biceps brachii of five young males and CKC method [1] to identify 252 experimental motor unit action potentials (MUAPs). The latter were convolved with synthetic MU firing patterns [2] yielding 10 s long hdEMG signals. The muscle excitation level was set to 10 % resulting in 52 active MUs. In each out of 10 generated hdEMG signals MUAPs were randomly selected. The CKC method was applied to the signals to identify individual MU firings. For each MU, all the identified firings were classified as true positives (TP), false positives (FP) and false negatives (FN) with a firing detection tolerance set to 0.5 ms. Finally, the PNR metric was calculated in three different scenarios: a) for all the TP firings, b) for all TP + one FP firing and c) all TP + one FN firing. Scenarios b) and c) were repeated for all the identified FPs and FNs per MU.

RESULTS: On average, the identified MU firings contained 135 ± 15 TPs, 6 ± 7 FPs and 4 ± 7 FNs. In 10.5 ± 1.5 out of 13.4 ± 2.3 identified MUs, the values of PNR metric dropped significantly (Kruskal-Wallis test, $p < 0.05$) when FP firing was included (scenario b) vs. a)). In the remaining MUs, the decrease was not significant. For the FNs (scenario c)), the significant decrease of PNR value was observed in 2.8 ± 0.9 out of 3.2 ± 0.9 MUs with FNs (Figure 1).

CONCLUSIONS: We analysed the sensitivity of PNR metric to FP and FN errors in MU firing estimation. In 78 % of identified MUs, the PNR decreased significantly when a single FP was included. These results suggest that the accuracy of single MU firing estimation can be assessed by comparing the of PNRs of MU spike trains with and without the tested firing. The FPs decrease the PNR value much more than TPs and FNs. ACKNOWLEDGEMENT: This study was supported by the Slovenian Research Agency (Programme P2-0041).

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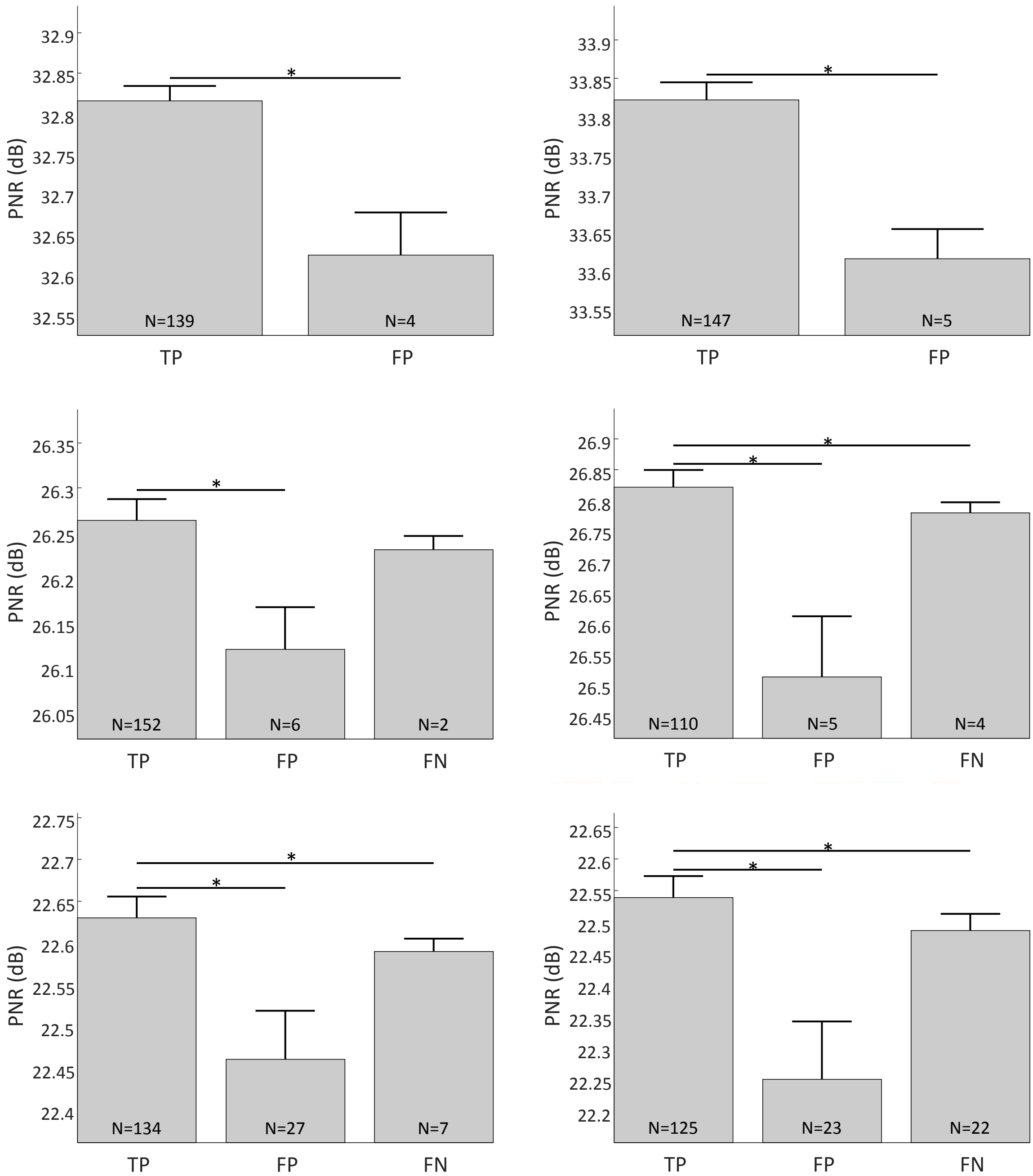

Figure 1. The number of TPs, FPs and FNs *(denoted by N)* and average PNR values, calculated in scenarios a), b) and c) for *different representative* motor units. The FPs decrease PNR values much more than FNs; * statistically significant difference (Kruskal–Wallis test, $p < 0.05$).

PI.17 Measuring the changes in Soleus EMG activity: Effect of electrode placements

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Background and Aim: Discrepancies in the measurement of the age-related strength decline in lower limbs has an adverse effect in analyzing the true muscle strength. This research has investigated the change in the electromyographic (EMG) activity of the lower limb muscle the soleus (SOL) muscle, which is a major part of the Triceps Surae. The change in the activity was studied between the two widely reported electrode placement protocols: SENIAM and Simoneau. Experiments were conducted where EMG was recorded while performing plantarflexion and dorsiflexion. Root mean square (RMS) of the EMG activity was computed and the statistical analysis was performed to identify the significance of the change in the measurements. The results show a significant difference in the RMS of the EMG activity recorded from soleus muscle between the two placement protocols. This change in the activity must be considered while computing the antagonist torque which is used in estimating the muscle coactivation.

METHODS: Electrodes were placed on the SOL using the following two placement protocols: a)SENIAM recommended the electrode location for the SOL at 2/3rd of the line between the medial condylis of the femur to the medial malleolus, Simoneau chose the placement a few centimeters from where the gastrocnemii join the Achilles tendon on the midline of the leg. The data was analysed for both bipolar and high density EMG recording. For the High Density EMG recording, single differential signal was computed between columns of electrodes 10 mm apart for each row, giving an inter-electrode distance of 10mm similar to the bipolar electrodes. The first and the final second of each recording were discarded because the force during these periods was not steady. Root Mean Square (RMS) was calculated for the remaining three seconds of recording for both the electrode positions on SOL.

RESULTS: The results show that RMS for the two different electrode placements for the SOL. It is observed that the RMS is significantly higher for the SOL in the 1st electrode position during dorsiflexion, and this was confirmed by Wilcoxon sign rank test ($p < 0.05$).

CONCLUSION: This study has investigated the change in the measurement of Soleus EMG activity due to the two different electrode placement protocols. The results have shown a significant difference in the RMS of the EMG activity recorded from soleus muscle between the two placement protocols. A consequence of the discrepancy between the two electrode placements will be evident in the calculation of the EMG/force relationship to estimate the true dorsiflexion agonist force.

PI.18 Evaluation of the Biomechanics and Neuromechanics of Lifting Tasks for the Real-Time Control of Electrical Stimulation

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INTRODUCTION: Lifting is a vital part of everyday life and work for many people; neural, muscular and articular systems must function together to complete the lifting action safely. Electrical stimulation can be used to increase abdominal muscle recruitment; it is thought that doing so during lifting will increase abdominal stability and spinal stiffness, reducing injury likelihood. Wearable sensors, such as accelerometers, can detect a range of body movements. In this study we developed an accelerometer based algorithm to detect lifting, and tested its reliability in detecting lifting and disregarding false positives; this was then interfaced with an electrical stimulation system to initiate stimulation in real-time upon lift detection.

METHODS: An initial data collection was performed to establish optimal accelerometer position for lift detection, and obtain the acceleration characteristic of lifting at this position. 10 subjects performed static squat and stoop lifting tasks; force plate and video data of these tasks were obtained for movement verification. The T12 level at the spine was found to be optimal for lift detection. A lift detection algorithm was developed utilising the acceleration Signal Magnitude Vector, Signal Magnitude Area, slope, and zero crossings. A final data collection was performed to test the robustness of this algorithm. 9 subjects performed a number of static squat and stoop lifting tasks, as well as walking and walking into lifting tasks. Again, video data was obtained for movement verification. Subsequently, an expert walkthrough, involving a physiotherapist with experience in electrical stimulation, was also performed. The expert performed lifting and walking tasks with stimulation being delivered to the abdomen in real-time upon lift detection; this evaluated the effect of electrical stimulation application during lifting tasks.

RESULTS: Median algorithm sensitivity is 100% for both static squat and stoop lifting, and for dynamic squat lifting; it falls to 88% for dynamic stoop however (Fig 1.1). Algorithm precision has a median of 100% for both static squat and stoop lifting, and dynamic squat lifting; this falls to 90% for dynamic stoop lifting (Fig 1.2). Median accuracy is 100% for static squat and stoop lifting, falling to 90% and 80% for dynamic squat and stoop lifting respectively (Fig 1.3). Squat lifting was more reliably identified in both static and dynamic conditions. The expert walkthrough concluded that electrical stimulation did not have a detrimental effect on lifting.

CONCLUSION: The sensitivity, precision, and accuracy of the developed algorithm are reasonable for an initial pilot study, and indicate that a single accelerometer can be used to identify lifting movements in real-time. Coupled with the feedback obtained from the expert walkthrough, these results indicate that a system utilising real-time electrical stimulation during lifting tasks could be viable and beneficial.

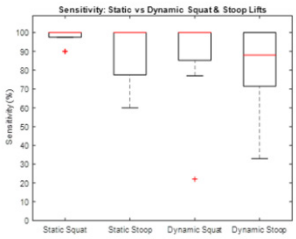

Figure 1.1

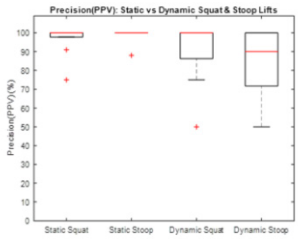

Figure 1.2

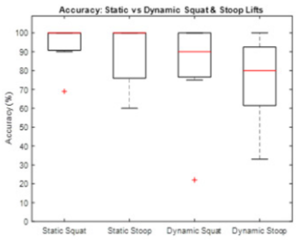

Figure 1.3

PI.19 Investigation of Two Channel Surface Electromyogram Measurement in Lower Extremities for Wearable Devices Targeting Periodic Limb Movements Detection at Home

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BACKGROUND AND AIM: Periodic limb movements (PLMs) are involuntary, repetitive, stereotypic, short-lasting segmental movements in the lower extremities during sleep, and may associated with cardiovascular diseases due to the sudden rise of blood pressure. Though PLMs themself are benign when the number is small, but among the patients of Periodic limb movements disorder (PLMD), one of the sleep disorders, consecutive PLMs cause nocturnal awaking and decrease sleep quality, so that its early detection and appropriate treatment are important. In the medical setting, PLMs and its benign/malignant condition are measured by polysomnography (PSG) with surface electromyogram (SEMG) of bilateral anterior tibialis because there are no PLMs detection devices with medical approval except for it. However, there might be some potential PLMD patients who have not taken PSG and remain untreated due to the financial and time burden of PSG. Furthermore, even among the diagnosed PLMD patients, they are also hard to appropreately know the PLMs from the viewpoint of number of epochs or its benign/malignant condition during sleep without PSG. To improve PLMD patients treatment along with their symptoms, we aim to develop a wearable SEMG devices for PLMs detection at home with textile-based electrodes and adaptors, which can be used in usual sleep at home and easily handled by the patients without any medical knowledge.

METHOD: In this paper, we report on a preliminaly evaluation which aimed to appropreately distinguish PLMs from other body movement regardless of the user's physique. We conducted three steps to clarify the target muscle: (1) confirmation of PLMs, muscle activity, and muscle innervation, (2) confirmation of muscle activity while PLMs, and (3) selection of target muscle and SEMG measurement during sleep. In the first step, we confirm PLMs definition in sleep medicine and specify the candidate muscles whose muscle activity can be easily measured by SEMG based on biomechanics as well as its innervation. We secondly confirm the muscle activity of the candidate muscles and its relationship to other candidate muscles while actual PLMs, and lastly select the target muscles for PLMs detection at home based on aforementioned results. We chose abductor hallucis and tibialis anterior as a preliminaly evaluation target whose dominant nerve is different from wach other.

RESULTS: The overnight experimental result shows that there are some possible PLMs occurred along with the change of sleep stage as defined in sleep medicine. Furthermore, most possible PLMs are related with both muscles, but some of them occurred only in abductor hallucis.

CONCLUSIONS: Two-channel SEMG measurement including at least tibialis anterior and abductor hallucis is effective for detecting PLMs at home without using any other biosignals.

PI.20 Development of MMG / EMG Hybrid Transducer System for Muscle Contraction Evaluation during Dynamic Exercises

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BACKGROUND AND AIM : The simultaneous measurement of mechanomyogram (MMG) and electromyogram (EMG) could be useful for evaluation of muscle contraction. Unlike the EMG, the MMG is rarely used in clinical field, because the target muscle has to be fixed during MMG measurements and it was impossible to measure the MMG during dynamic exercise. The aim of this study is a development of a displacement-MMG (d-MMG) / EMG hybrid transducer system that could achieve the simultaneous measurements of the MMG/EMG during dynamic exercise, and the proposal of analysis method which could evaluate muscle contraction by means of the power spectra of each signal.

Methods: The authors developed a novel MMG/EMG hybrid transducer system to actually adapt in various fields from the research stage and also proposed an analysis method for evaluating d-MMG during dynamic exercise. Figure (A) shows the hybrid transducer whose size and weight were 47 × 34 × 24 mm and 34 g. The MMG sensor of this transducer used a photo reflector. The swelling of skin surface caused by the muscle contraction was recorded as the d-MMG and the dynamic range was 1-8 mm. A personal computer controlled the transducer via Bluetooth®. In order to affix the transducer to the skin, we made an exclusive belt that could be easily wrapped around the leg or arm (Figure (B)). We developed a measurement/control software that can collectively operate up to five hybrid transducers and display up to 10 windows of real-time d-MMG and EMG signals (Figure (C)). The sampling frequency could be set from 1 to 1 kHz and the signal data temporarily stored in binary format to an SD card through a 12-bit ADC. We also proposed a novel analysis method for the evaluation of dynamic muscle contraction. In the case of dynamic exercise (e.g. recumbent bicycle pedaling), the target waveforms of d-MMG and EMG were processed with a Hamming window and a discrete Fourier transform. Finally, the total power (area value) of the power spectrum below 100/500 Hz was calculated as an index of the dynamic muscle strength (d-MMGFT and EMGFT, respectively).

RESULTS : This study was conducted according to the principles of the Declaration of Helsinki and with ethical approval from the Okayama University Ethics Committee (1703-013). In the case of recumbent bicycle pedaling (C545R, SportsArt, USA), the d-MMGFT and EMGFT of the vastus medialis muscle of four subjects increased as the pedaling work rate increased (51, 68, 80, 99, and 108 W).

CONCLUSIONS: The developed the MMG/EMG hybrid transducer system and the proposed analysis method were useful for the simultaneous measurement of the d-MMG/EMG and the evaluation of muscle contraction during dynamic exercise. ACKNOWLEDGEMENT : This research was partially supported by a Grant-in-aids for Scientific Research (17K01360) from Japan Society for the Promotion of Science.

PI.21 Assessment of breathing effort using surface diaphragm electromyography: preliminary results

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BACKGROUND AND AIM: Obstructive sleep apnea (OSA) affects over 9% of the adult population in western countries, with many undiagnosed cases. Assessment of respiratory effort is essential in the detection of breathing-related arousals; it can be obtained by the product of air flow and alveolar pressure. However, the gold standard technology for measuring alveolar pressure (esophageal manometry) is invasive and hence unpractical for long-term monitoring overnight, specifically in children. The aim of this study is to investigate the feasibility of using surface diaphragm electromyography (SD-EMG) to measure respiratory effort.

METHODS: Five healthy volunteers (age: 26.7±2.2) participated in this study. First, they performed a normal mouth breathing through a spirometer (air flow below 1 L/s) by using a nose clip to prevent nasal flow. Real-time air flow was measured by the spirometer sampled at 100 Hz. Next, they performed breathings with different airway resistances while maintaining constant air flow. The resistance consisted of cylinder sponge pieces with diameter of 32 mm and length of 15 or 25 mm inserted in a PVC tube between the mouth and the spirometer. All the trials were performed in sitting position for 50 s with 2-minute interval in between. SD-EMG was measured by six monopolar Al/AgCl electrodes placed between the sixth and eighth intercostal space on the right side of the body. A ground electrode was placed on the right clavicle and a reference electrode on the mid-nipple line. The SD-EMG signal was recorded by a Porti amplifier sampling at 2048 Hz. The SD-EMG signal was first filtered between 20-250 Hz. Next, the QRS complex was removed by setting 400-ms signal around each R peak to zero. The mean square (MS) value of each channel was calculated to estimate EMG power using a 1-s, non-overlapping window. For the normal breathing test, the correlation coefficient between the averaged EMG power (over all the channels) and the air flow was calculated. For the breathings with different resistances, the EMG power during inspiration was identified and then averaged. The difference in EMG power between different resistances was assessed by Wilcoxon signed rank test.

RESULTS: The same number of respiration cycles was observed during normal breathing both in the spirometer signal and the EMG power for each subject. The average correlation coefficient between EMG power and air flow was 0.68±0.14. The average EMG power during inspiration was 222±236 μV^2 for 25 mm sponge and 120±84 μV^2 for 15-mm sponge. However, the difference was not significant (p=0.22).

DISCUSSION AND CONCLUSIONS: The correlation between EMG power and airflow during normal breathing shows the ability of SD-EMG to track respiration cycles. Non-significant difference in EMG power between different resistances was found, motivating further investigation with larger groups to elucidate on the feasibility of SD-EMG to measure respiratory effort.

PI.22 Estimating Quasi-Static Joint Mechanical Impedance from EMG via Training from a Single Trial

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[1]Worcester Polytechnic Institute, [2]University of North Carolina-Chapel Hill and North Carolina State University, [3]University of Sherbrooke

BACKGROUND: Quasi-static joint mechanical impedance is typically modeled at a single operating point (i.e., single background torque level) as a second-order linear system relating changes in joint angle to changes in joint torque. Experimentally, impedance parameters of inertia, viscosity and stiffness are trained by applying perturbations to the joint. Measurements at distinct operating points are cumbersome and not practical when it is desired to monitor impedance during active tasks. In this study, we related the EMG signal standard deviation (EMG?) to impedance about the elbow during a single 50 s task in which the background torque was slowly ramped from 40% MVC extension to 40% MVC flexion, while the joint was randomly vibrated by a manipulandum. In practice, the arm could be removed from the manipulandum after this training task, and then EMG alone used to estimate impedance.

METHODS: Seven subjects had bipolar EMG electrodes placed over each of their biceps and triceps muscles. Subjects sat in an experimental apparatus and were cuffed to a manipulandum at their wrist. After calibrating for elbow extension and flexion MVC, subjects produced a quasi-static background torque (one of 10, 20, 30 or 40% MVC extension or flexion) with mechanical perturbations superimposed (15 Hz, Gaussian distribution of zero mean and 0.8 Nm standard deviation). EMG, force and resulting arm kinematics were recorded for 30 s. Next, the background torque was slowly ramped from 40% MVC extension to 40% MVC flexion over 50 s, the same perturbations were applied, and data recorded. Off-line, linear regression was used to relate the change in angle to change in torque as a second-order linear system. We then compared impedance parameters estimated from data obtained with quasi-static versus ramp force exertion trials.

RESULTS: Impedance values determined during the ramp trials were extracted at the 8 effort levels corresponding to the quasi-static trials. For each of these 8 effort levels, viscosity and stiffness were compared (static vs. ramp) using one-way RANOVAs. Viscosity values differed statistically ($p<0.05$) at 10 and 20% extension, and at 10% flexion. The strength of these average differences was modest (15-25%). There were no statistically significant differences for stiffness.

CONCLUSION: The common measures of muscular co-activation, such as co-contraction index and ratio, have shortcomings, including that they are relative measures, can give the same measure for very distinct effort levels and do not have physical units. Joint mechanical impedance is a robust measure, with physical units. But, experimental measurement of this impedance is time consuming and perturbs the task under study. In contrast, EMG-impedance was shown herein to be generally similar in performance to direct mechanical measures. Once the EMG-impedance model has been formed, viscosity and stiffness can be estimated from the EMG alone without the need for mechanical perturbations.

MOTOR CONTROL

PI.23 Neck electro-tactile stimulation induces forward leaning during upright posture

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BACKGROUND AND AIM: Sensory information conveyed along afferent fibres from muscle and joint proprioceptors play an important role in the control of posture in humans. Previous studies have shown that proprioceptive afferences from the neck region, evoked using muscle vibration, lead to strong body orienting effects during static conditions (e.g. leaning of the body forwards). However, it is not yet certain whether the proprioceptive receptors located in the deep skin (cutaneous mechanoreceptors) have a substantive contribution to postural control, as vibratory stimulation encompasses the receptive field of all the proprioceptive receptors from the skin to the muscles. The aim of this study was to investigate the postural effect of cutaneous mechanoreceptor afferences using electro-tactile stimulation applied at the neck.

METHODS: Ten healthy subjects agreed to participate in this study. The position of their centre of foot pressure (CoP) was acquired before, during and after a subtle electro-tactile stimulation over their posterior neck (Mean ± SD = 5.1 ± 2.3 mA, 1 ms biphasic sinusoid at 100 Hz - 140 % of the perception threshold) during upright stance with their eyes closed. The acquisition trial was divided into 30 s consecutive phases, Pre (stimulation off), Stim (stimulation on) and Post (stimulation off) and repeated three times. Mean position and standard deviation (SD) of the CoP oscillations, along the antero-posterior (A-P) and the medio-lateral (M-L) direction, were calculated. Statistical evaluations were performed using a one-way repeated measures analysis of variance (ANOVA) across the three acquisition phases (Pre, Stim Post) followed by Bonferroni corrected t-tests when ANOVA was significant ($p<0.05$).

RESULTS: Mean ± SD of the CoP A-P position was 12.08 ± 11.88 mm and -2.5 ± 7.03 mm at Stim and Post, respectively (compared to Pre phase), indicating a net forward movement of the mean CoP position of approximately 1.2 cm, induced by the stimulation. The mean CoP A-P position during the Stim phase was statistically different from the Pre and Post phases ($p = 0.031$ and $p = 0.046$, respectively). The mean CoP M-L position as well as the average SD of the CoP A-P and M-L oscillations did not show any significant changes.

CONCLUSIONS: In healthy young subjects a clear anteropulsion of the body is induced via subtle electro-tactile stimulation of the posterior aspect of the neck. This study is the first showing such a postural effect arising from the stimulation of the cutaneous mechanoreceptors of the neck. The effect has a clear direction along the antero-posterior axes of the body. However, as the stimulation was delivered with large electrodes, likely stimulating in a symmetric way the left and right side of the neck, the possibility for net postural effects along the medio-lateral axis might be discarded. Neck electro-tactile stimulation might be used to induce forward leaning of the body towards a safer standing position as optimisation of postural control, induced via motor learning, leads to a forward shift of the CoP (Tarantola et al. 1997).

PI.24 Trunk Muscle Activation Patterns Interact with Clinical Instability to Influence Low Back Reinjury Risk

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[1]Dalhousie University, [2]Canadian Armed Forces

BACKGROUND AND AIM: Clinical instability (CI) assessments identify individuals with passive stability impairments who benefit from altered muscular recruitment training1. Those with CI appear to modify trunk muscle activation to increase spinal stiffness2. However, these effects are small and may reflect variability within the group to alter active stiffness in a manner consistent with reducing risk of future low back injuries (LBI)3. The purpose of this study was to determine whether a CI classification would interact with trunk muscle activation patterns to modify the risk of future LBI.

METHODS: Thirty-two recovered LBI participants (4-12 weeks post injury with minimal pain and disability) were recruited and classified as having (CIG n=12) or not having a CI (NCIG N=20) based on a clinical assessment1. Participants performed a controlled supine leg loading task timed to an external count (Fig). Surface electromyograms (EMG) were digitized from 24 trunk muscle sites (12 abdominal and 12 back extensors) at 1000Hz, full-wave rectified, low-pass filtered (6 Hz), time normalized to 100% and amplitude normalized to maximum voluntary isometric contractions. EMG ensemble-average waveforms were calculated for each muscle site and participant. Waveform features were captured using principal component (PC) analysis models constructed separately for abdominal and back sites. Participants were further categorized as reinjury (RE, n=15) or no-reinjury (NoRE, n=17) based on 1 year follow-up (self-identified LBI limiting activity for > 3 days). Mixed model ANCOVA (group, reinjury, and muscle; covariate: strength) were conducted on PC scores ($\alpha=0.05$).

RESULTS: There was a significant PC3 group by reinjury interaction for the abdominals. In the CIG, NoRE had less reduction in activity during right leg lowering than RE (Fig-Red), where in NCIG, NoRE had a greater reduction than RE (Fig-Pink). For the back sites, two features had group by reinjury interactions. PC1 captured higher antagonist activation amplitudes for, NoRE than RE in the CIG, where in the NCIG, RE was higher than NoRE. PC2 captured that in CIG, NoRE had less difference between, right leg lift/lower and no leg support, than RE (Fig-Red).

CONCLUSIONS: The findings show that in those with clinical instability, higher antagonist co-activation (PC1) and sustained activity (PC2 and 3) may be adaptations linked to a reduced risk of reinjury. These adaptations are consistent with increased spinal stiffness throughout the movement as an adaptation to the passive instability. Of interest was that the same muscle activation patterns in those with no clinical instability were linked with future injuries. These findings support a need to consider a person's specific spinal impairments when implementing therapies that target muscle activation.

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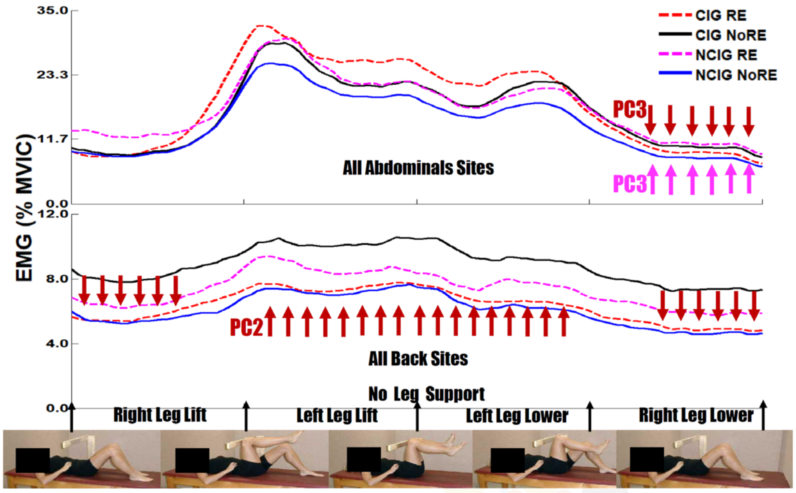
CIG RE
CIG NoRE
NCIG RE
NCIG NoRE
35.0
23.3
11.7
0.0
12.0
8.0
4.0
0.0
EMG (% MVIC)
PC3
PC3
All Abdominals Sites
PC2
All Back Sites
No Leg Support
Right Leg Lift
Left Leg Lift
Left Leg Lower
Right Leg Lower

PI.25 Regularity of force control in individuals with and without a recent anterior cruciate ligament rupture

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BACKGROUND AND AIM: Musculoskeletal injuries and disorders are characterised by changes in neuromuscular control. The loss of complexity hypothesis suggests that with ageing, injury and disease, there is a deterioration in physiological function,variability of movement and force output. This may manifest as reduced complexity and contribute to increased injury risk as the biological system is less adaptable. Sample entropy (SaEn) is a measure of the ‘complexity’ and variability within physiological time-series signals. Greater entropy is suggestive of a system with complex dynamics, more irregularity and randomness; thereby providing for a highly adaptable neuromuscular system. Impaired systems (e.g. following anterior cruciate ligament (ACL) injury) may exhibit lower SaEn compared to healthy systems, suggesting a more predictable system that is less able to adjust to external perturbations and produce force accurately.

METHODS: Ten individuals with unilateral isolated ACL injury (7M/3F; 28.1 ± 8.1years; 56.3 ± 36.1 days post-injury) and 12 healthy individuals (10M/3F; 29.4 ± 7.5years) participated in the study. Participants performed an isometric open kinetic chain quadriceps contraction to match an increasing force ramp from 5% to 25% body weight (BW), after which the ramp decreased from 25% to 5% BW (0.10Hz). Four trials of 60s duration with 60s rest in between were performed. Following published methods, force regularity was evaluated using SaEn of quadriceps force-time output using an embedding dimension of 2 and a tolerance distance of 0.2 x SD of the force output for each sub-region. Ascending SaEn and descending SaEn was compared between groups and limbs. The association between SaEn and patient-reported knee function (KOOS) was assessed.

RESULTS: There was significantly higher ascending SaEn in the injured limb of the ACL group compared to healthy controls (0.048 ± 0.016 INV limb; 0.046 ± 0.009 UNINV limb; 0.036 ± 0.007 CONT; 0.040 ± 0.011 UNINV CONT P=0.012). The ACL group also had significantly higher descending SaEn in the injured limb compared to healthy controls (0.041 ± 0.014 INV limb; 0.039 ± 0.011 UNINV limb; 0.032 ± 0.006 CONT; 0.035 ± 0.008 UNINV CONT P=0.045). No significant associations were found between SaEn and KOOS (P>0.05).

CONCLUSIONS: Poor quadriceps neuromuscular control is common following ACL injury and may contribute to greater SaEn (more irregular force) observed for the injured limb in this study. Although greater entropy could be beneficial during more complex and variable tasks (e.g. adapting the neuromuscular system to walking on uneven ground), the greater entropy observed during this more constrained open kinetic chain task may be indicative of poor neuromuscular control.

PI.26 Effects of low-intensity vibration exercise on muscle activation

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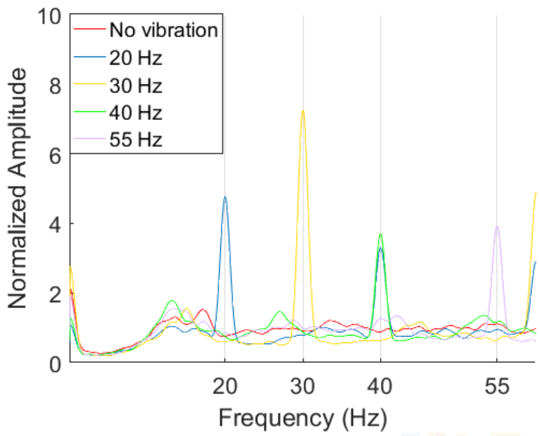
BACKGROUND AND AIM: Vibration Exercise (VE) has been suggested to improve muscle strength and power performance at lower training intensity. These effects have been partially ascribed to a reflex mechanism named tonic vibration reflex (TVR). However, the neurophysiological response during VE is still not fully understood. This study aimed at investigating the effects of VE on motor unit (MU) recruitment strategy in order to clarify the underlying neuromuscular mechanisms elicited by VE.

METHODS: Twenty healthy volunteers participated in this study. They sat on a fitness bench with the back straight and elbow at 90 degrees. A force-modulated VE system was employed to apply a sinusoidal oscillating force to the subject's dominant arm. The subjects performed 30-s isometric contractions with different (randomized) vibration amplitudes (12.5%, 25%, and 50% of the baseline force) and frequencies (0, 20, 30, 40, and 55 Hz). The baseline force was set at 30% of the maximum voluntary contraction (MVC), measured by a load-cell embedded in the VE system. Surface EMG was measured on the biceps by two 8×8 Ag/AgCl electrode grids (4 mm diameter, 8 mm inter-electrode distance) aligned with the muscle fibers. An Ag/AlCl electrode with 1-cm diameter was placed on the clavicle as ground. The EMG signal was recorded by a 136-channel Refa amplifier sampling at 2048 Hz. EMG conduction velocity (CV), mean frequency (MF), fractal dimension (FD), and root mean square (RMS) value were extracted as indicators of MU recruitment strategy. The first 2-s EMG data was ignored to avoid transient contraction. The following 10-s data was used to calculate the indicators. The signal was first band-pass filtered from 15 to 450 Hz. A bipolar signal, obtained by averaging over two subsets of channels, was used to calculate the MF, FD, and RMS. The rows between the innervation zone and the muscle tendon, identified by visual inspection, were used to estimate the CV by a maximum likelihood method. For each parameter, the difference between each vibration trial and control condition was assessed by Wilcoxon signed rank test.

RESULTS: CV showed significant increase for all VE trials as compared to no vibration ($p < 0.05$). RMS value showed significant increase at 30, 40, and 55 Hz with vibration amplitude at 25% and 50% of the baseline force. No statistical difference was obtained in MF and FD.

CONCLUSIONS: The observed increase in CV and RMS during VE indicates vibration-induced variation in the MU recruitment strategy, i.e., activation of large and faster MUs. No significant increase in MF was observed, possibly due to TVR, causing a decrease in MF, or to increased sensitivity of MF to the spatial location of the activated MUs. No clear trend was observed in FD, suggesting some involvement of the central nervous system during VE to increase the neural drive complexity and, therefore, to compensate for possible FD decrease due to TVR.



PI.27 Sit-to-stand task muscular pattern for different backrest inclinations

Nadège Tebbache, Alain Hamaoui
I.N.U Champollion

BACKGROUND AND AIM: The sit-to-stand (STS) transfer is a daily demanding locomotor task, prerequisite for many activities and crucial for autonomy. It has been shown that this movement involves the mobilization of a large part of the kinematic chain, which should require a wide muscular pattern. Surprisingly, literature analysis showed that most electromyographic studies have focused on a limited number of muscles, mainly in the lower limb. Furthermore, few attention has been given to the effect of backrest inclination, although it is a very common adjustable parameter in many categories of seats (resting, office, transportation...).The aim of this study was therefore to analyze the activation pattern and level of activity of a wide range of muscles along the chain during a STS task for different backrest inclinations.

METHODS: An electromyographic analysis of 15 muscles of the neck, torso, and lower limb during a STS task was performed. Designed as a pre-test of an extended study including a biomechanical analysis using force plate data, this study was undertaken by 10 participants (6 F - 4 M) requested to stand up from an airplane seat with 5 different conditions of backrest inclination at their comfortable and maximal speed.

RESULTS: Results showed that 10 out of the 15 investigated muscles presented a mean rectified value above 10% MVC in at least one of the conditions. Muscle activation pattern was stable across subjects and conditions, with an early activation of the sternocleidomastoid, rectus abdominis, external oblique and tibialis anterior. Backrest reclination significantly increased the activity of the SCM, neck extensors and the abdominal muscles, with the highest angle (40°) standing out.

CONCLUSIONS: Those results highlight the heavy demand of the sit-to-stand task, requiring a coordinated activation of many muscles from the head to the feet. Reclining the backrest did not require a reprogramming of the muscular pattern, but a higher activity of trunk and neck muscles, with no variation in the lower limbs. As a consequence, it can be assumed that the overload associated with a reclined backrest is only supported by trunk and neck muscles.

PI.28 Co-contraction in the lower extremity postural control muscles during continuous support-surface perturbations is reduced with previous experience.

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BACKGROUND AND AIM: Maritime workers have a high risk of slip-, trip-, and fall-related injuries,1 and there is a further increase in risk for young (i.e. inexperienced) workers.2 Previous work found that individuals with previous experience on a laboratory motion platform demonstrated reduced average lower extremity muscle activation levels during postural control tasks on the platform, compared to those with no experience.3 However, examination of the muscle activation patterns required to maintain balance is needed. This secondary analysis4 aimed to determine how short-term and long-term experience influence muscular activation patterns during postural responses to continuous, multi-directional support-surface perturbations.

METHODS: Participants consisted of 25 individuals (12 with no maritime work experience (novice group); 13 with ≥6 months of maritime work experience (experienced group)). Participants were exposed to five 5-minute trials of simulated maritime motion, during which they moved their feet whenever they needed to maintain balance. During these trials, activation amplitudes of six muscles on the lower extremity and pelvis were measured bilaterally using surface electromyography. The co-contraction index5-7 was used to quantify similarities in the magnitude and timing of activation for selected pairings of muscles over each 5 minute trial. These values were then compared between groups (experienced/novice) and across trials (trials 1-5).

RESULTS: Co-contraction was consistently greater in the novice group compared to the experienced group, and decreased across trials. For muscle pairings with significant interaction effects of group and trial, reductions in co-contraction across trials were more substantial for the novice group compared to the experienced group, such that the difference between the two groups decreased from trial 1 to trial 5.

CONCLUSIONS: Our results indicate that long-term experience enables individuals to respond to external perturbations with less co-contraction, although short-term experience with these perturbations also leads to further reductions in co-contraction. These findings further our understanding of reactive balance control during continuous support-surface perturbations in simulated maritime environments, as well as the role of previous experiences on reactive balance strategies. Applications may include the development or improvement of training programs for novice workers in maritime environments, in order to reduce falls and injury risk at work.

REFERENCES: [1]Jensen et al. Am J Ind Med 2005;47(2):161-71. [2]Jensen. Am J Ind Med 2000; 2000;37:637-44. [3] Ingram et al. Theor Issues Ergon Sci 2016;17(3):324-36. [4]Duncan et al. PLoS One 2016;11(11):e0165735. [5]Lewek. Osteoarthr Cartil 2004;12:745-51. [6]Nelson-Wong & Callaghan. J Electromyogr Kinesiol 2010;20:256-63. [7]Rudolph et al. Knee Surg Sports Traumatol Arthrosc 2000;8:262-9.

PI.29 Sex-differences in surface electromyography during pull-up tests

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Background and Aim: Sex-differences in surface electromyography (SEMG) have been reported during single, sustained and painful conditions. Still, it is not completely known if such sex-differences exist during single and repeated pull-ups until task failure. We hypothesized that SEMG activity would be higher in females compared with males during single and repeated pull-ups until task failure.

METHODS: In total, 27 asymptomatic cross-fitters took part in this study (14 males and 13 females). The SEMG of the right biceps brachii (BB), latissimus dorsi (LD), lower trapezius (LT) and pectoralis major (PM) were recorded in agreement with the SENIAM guidelines. The absolute and normalized root mean square (RMS) values were computed over 1-s epochs. The absolute RMS values were normalized values with respect to the maximal SEMG activation measured during maximum voluntary contraction performed in isometric conditions. The single pull-ups were performed at a 1 Hz frequency (metronome) following a 2-s:1-s:2-s scheme, that corresponded to the time under tension during the concentric, isometric and eccentric lifting phase, respectively. The fatigue protocol applied to repeated pull-ups was performed at a self-chosen frequency until task failure. Three-way analyses of variance (ANOVA) with sex, muscle and lifting phase or time were carried out for both absolute and normalized RMS values.

RESULTS: For single pull-ups, there was significant interaction between muscle and lifting phase for both absolute and normalized RMS ($F=2.3$, $P<0.05$ and $F=3.5$, $P<0.01$). The normalized RMS values were higher for females than males. For repeated pull-ups, similar results were seen for absolute and normalized RMS values. Further, there was significant interaction between sex and muscle for absolute and normalized RMS values ($F=6.9$, $P<0.001$ and $F=5.2$, $P<0.01$) and between time and muscle ($F=5.7$, $P<0.001$ and $F=2.8$, $P<0.05$). The RMS values increased over time until task failure. Males executed significantly more pull-ups than females ($P<0.001$). For the interaction in absolute RMS values of sex and muscle, the males produced significantly higher amplitudes for BB and LT ($P<0.05$). However, for the normalized RMS, females used relative higher ratio for PM, BB and LD than males during the repeated pull-ups ($P<0.05$).

CONCLUSIONs: The present study showed sex-differences in SEMG activation during both single and repeated pull-ups. The higher normalized SEMG activity found among females compared with males most likely explained that females performed fewer pull-ups.

PI.30 Intermuscular coherence in the trunk muscles during gait: does fear of movement in chronic low-back pain patients affect intermuscular coherence?

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BACKGROUND AND AIM: Corticospinal drive appears altered in patients with chronic low-back pain (LBP). Corticospinal drive can be assessed with intermuscular coherence (IMC). However, IMC has to our knowledge not been reported for trunk muscles. Therefore, our first aim was to determine whether intermuscular coherence in the beta- and low gamma band occurs in the trunk muscles during gait. Current literature is inconsistent on whether corticospinal drive is increased or reduced in LBP patients compared to healthy controls. These inconsistencies might suggest subgrouping in LBP patients. Previously, fear of movement has been used to define subgroups of LBP patients, and LBP patients with more fear of movement show higher trunk muscle activation compared to patients with less fear of movement. Therefore, our second aim was to investigate whether LBP patients with more fear of movement have a different IMC between trunk muscles during gait, compared to patients with less fear of movement.

METHODS: Thirty-two LBP patients participated in this study. Two subgroups were created based on the median split of the Tampa scale of kinesiophobia (TSK), a high fear of movement group (TSK score >44) and a low fear of movement group (TSK score <42). The experiment consisted of four walking conditions on a split-belt treadmill. Electromyography of eight bilateral trunk muscles was measured. Strides were sectioned in four phases: double support left, single support left, double support right and single support right. Intermuscular coherence (IMC) in the beta (15-35 Hz) and low gamma (30-60 Hz) band were calculated between bilateral homonymous, ipsilateral heteronymous and contralateral heteronymous trunk muscle pairs. In total, 35 trunk muscle pairs were analysed. The area of coherence (Coharea), the integral of the absolute coherence over the frequency band of interest, was extracted from the coherence spectra for every gait phase and for every condition. A three-way mixed design ANOVA was performed to detect statistical differences.

RESULTS: Significant IMC was shown in 14 and 9 of 35 trunk muscle pairs in the beta and gamma band, respectively. ANOVA showed that IMC was influenced by walking speed and gait phase, except for the bilateral muscle pairs. The high fear of movement group showed higher IMC for only 2 of the 16 contralateral muscle pairs, compared to the low fear of movement group.

CONCLUSION: This study provides evidence that some trunk muscle pair show IMC during gait and that trunk IMC is affected by walking speed and gait phase. These results support the possibility of using trunk IMC as a marker of corticospinal drive in LBP. Two of the sixteen contralateral muscle pairs showed significant differences between subgroups. The limited differences between subgroups might give directions for future research on subgrouping of LBP patients, but as it may reflect a false positive result, replication in an independent sample is necessary.

PI.32 Reduced sensory input from the feet affects mechanical role of muscle synergies but not related muscles

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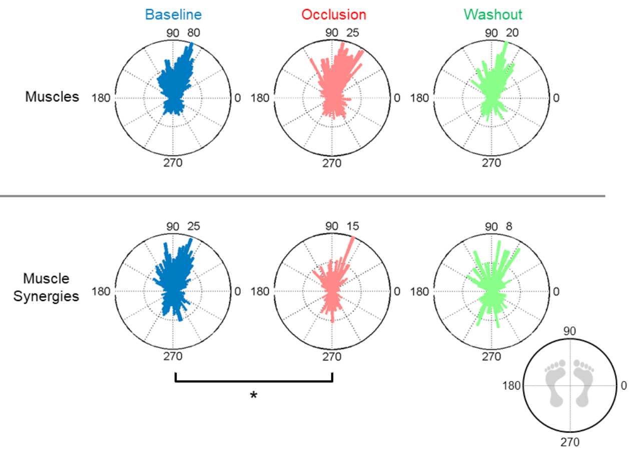
BACKGROUND AND AIM: In maintaining upright stance, sensory information from the feet has a smaller effect on stability than proprioceptive or visual information (Fitzpatrick et al., 1994). However, we have to keep our center of foot pressure (COP) in various directions in everyday life and the importance of sensory input from the feet in such a task is unknown. To move COP to multi-direction, it is necessary to co-activate muscles in several body segments. Muscle synergy, the coordinative structure of muscles is said to be essential in such cooperation (Imagawa et al., 2012). Our goal was to clarify the effect of sensory input from the feet on muscle synergies activated in multi-directional postural control.

METHODS: Subjects shifted their COP from the original position to the target point by leaning their body and then holded the target COP position for 10 s. They viewed the desired COP position as a target on a visual display. In each block, subjects performed COP displacements toward 12 different targets distributed equally over the horizontal plane. In first 20 blocks (baseline), all sensory inputs were available. In following 7 blocks (occlusion), sensory input from the feet was weakened by local anaesthesia from prolonged ischemia at 300 mmHg, induced by occluding blood flow with inflated pneumatic cuffs just above the ankles. In next 4 blocks (washout), pneumatic cuffs were removed. Using non-negative matrix factorization, we extracted muscle synergies from surface EMGs recorded from 18 muscles spanning ankle, knee and hip joints. In each trial, the electromyogram weighted averaging (EWA) direction (Kutch et al., 2010) was determined as the first peak of the cross-correlation coefficient between the fluctuations in activation of muscle synergies and COP within the time lag from 50 to 150 ms.

RESULTS: Error in each target direction was quantified as distance between COP and target point. Compared to baseline blocks, error in occlusion blocks was significantly increased in left-right and diagonal direction, while error in anterior-posterior targets remained unchanged. Six to Eight muscle synergies were extracted from first baseline block in each subject, and the reconstruction of remaining blocks by these muscle synergies showed high variability accounted for (>80%), which means muscle synergies in baseline blocks were robust through occlusion and washout blocks. Using Kuiper test, significant difference in distributions of EWA directions of muscle synergies were detected between baseline and occlusion blocks, while those of muscles showed no difference.

CONCLUSIONS: Considering that EWA direction of each single muscle tends to concentrate in anterior-posterior directions and thus co-activation among several muscles is important in postural control in left-right or diagonal direction (Imagawa et al., 2012), these results imply that sensory input from the feet gives substantial information when muscles need to synergistically cooperated.



Distributions of EWA Directions of muscles and muscle synergies

PI.33 Simultaneous and Proportional Myoelectric Control for a Robotic Arm with Multilayer Perception Network and limited samples

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In this paper, we proposed a new simultaneous and proportional myoelectric control scheme for a robotic arm with multilayer perception network and limited samples. Our goal is to replicate the wrist's position using only surface EMG signals. To achieve this purpose the continuous angle of the shoulder and the elbow corresponding the simultaneous movement of the two joints must be estimated by EMG signals. The relationship between EMG and angles of elbow and shoulder was established by a multilayer perception network, multilayer perception network is one of the simplest forms of neural networks, as it is a feedforward neural network where information moves in the forward direction only. In our experiment, the network consists of 2 hidden layers, each layer has 50 units, the dropout parameter of the second hidden layer is set as 0.7 to avoid over fitting, the initial parameter is a normally distributed variable with variance 0.1, the loss function is root mean square (RMS), and there are 5 inputs (EMG channels) and 3 outputs (2 shoulder angles and 1 elbow angle). The EMG signals and angles are collected by the wireless EMG amplifier and biometric detectors, respectively, which were produced by Delsys corporation. The sampling rate of EMG and angles are both set as 1000 Hz. The width of the smooth window is 200 with overlap 180. The EMG signals are smoothed by the smooth window to extract the outline before sending to the multilayer perception network. The performance measures used were the root mean square error (RMSE), the correlation coefficient (CC). The experimental results show that the angles of the two joints can be exactly estimated by EMG signals by multilayer perception network with CC about 0.9. That means simultaneous and proportional control of the robotic arm or prosthetic arm can be achieve only by EMG signals.

Subject	Performance Measure	Single Elbow XZ	Single Shoulder XZ	Single Shoulder XY	Single shoulder YZ	Simultaneous XZ		Simultaneous XY		Simultaneous YZ	
						Elbow	Shoulder	ELB	Shoulder	ELB	Shoulder
1	RMSE (%)	0.1513	0.1281	0.2209	0.1507	0.2132	0.1908	0.1359	0.1128	0.1653	0.1273
	CC	0.9353	0.9602	0.8417	0.9102	0.8523	0.8741	0.9428	0.9732	0.9182	0.9408
2	RMSE (%)	0.1598	0.1235	0.1305	0.1309	0.1633	0.1731	0.1553	0.2198	0.2539	0.2148
	CC	0.9564	0.9584	0.9581	0.9541	0.9423	0.9186	0.9241	0.8603	0.8788	0.8724
3	RMSE (%)	0.1830	0.1321	0.1221	0.1161	0.2404	0.1900	0.1660	0.1068	0.2452	0.1124
	CC	0.9123	0.9312	0.9642	0.9605	0.8583	0.8782	0.9411	0.9746	0.8602	0.9391

PI.34 Impairments in motor units firing and recruitment due to diabetic polyneuropathy progression: a high-density sEMG study in isometric contractions

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BACKGROUND AND AIM: Impairment of motor neurons is a determinant of motor dysfunction in diabetic polyneuropathy (DPN). Axonal dysfunction, loss of motor units (MUs) and motor axons are examples of neural impairments commonly reported. Whether DPN affect the MUs' recruitment and firing patterns during voluntary contractions remains unknown. Our aim was to investigate if DPN leads to changes in the characteristics of MUs function during isometric contractions.

METHODS: Ten control subjects (49.4±9.6yrs) and 30 diabetic patients (59.5±4.6yrs, 12.0±7.0yrs of diabetes diagnosis, 204.5±79.9mg/dL blood glucose) were assessed for (i) vibratory perception (128Hz turning fork), (ii) tactile sensitivity (10g monofilament) and (iii) presence of typical DPN symptoms. These 3 variables were regarded as linguistic inputs in a fuzzy system to classify the DPN degree (score 0-10). Diabetic subjects were classified as non-DPN (GD; score≤2.5) or DPN (GN; score>2.5). Multichannel Surface EMGs (64 electrodes matrix: 16x4, OT Bioelettronica) were acquired during 20% of maximum isometric voluntary contractions (MVC) of tibialis anterior (TA), gastrocnemius medialis (GM) and vastus lateralis (VL) muscles. TA and GM were assessed with the knee in full extension and ankle in neutral position. VL was evaluated with the hip and knee respectively flexed at 90° and 45°. Force was measured by a knee and an ankle ergometer (strain gauge load cells). Contractions were performed twice for 10s. Monopolar EMGs were band-pass filtered (4th order Butterworth filter, 20-350Hz) and decomposed into their constituent trains of MU action potentials using an automated technique [1]. The coefficient of variation of inter-spike interval (ISICoV), the area under the curve (AUC; median and maximal) of MU action potentials and the cross-correlation coefficient (CC) of MUs' smoothed discharge rates were computed. The association between the MU' variables and DPN degree was assessed with Pearson correlation. Groups were compared using ANOVAs, followed by Bonferroni pairwise tests ($p<0.05$).

RESULTS: TA showed lower ISICoV, higher median and maximal AUC in DPN subjects. GM presented a decrease in ISICoV with DPN progression. According to Pearson's correlation all muscles showed a progressive increase in CC with DPN degree. Non-DPN subjects also showed alterations in TA, with higher maximal AUC and higher CC when compared to control subjects.

CONCLUSION: CC results revealed that DPN leads to a more similar firing pattern among MUs in both proximal and distal (ankle) muscles, suggesting either a stronger common drive in these patients or a wider range of axonal sprouting of degenerated MUs due to the DPN progression. It is also clear the broader impairment at the TA in DPN patients, which is in accordance to the literature.

ACKNOWLEDGEMENT: FAPESP (processes 2013/05580-5 & 2017/15449-4). References: [1] Holobar A & Zazula D. Trans Signal Proc 2007;55:4487-96.

Table 1. MUs characteristics (mean±SD) and firing patterns analyzed for 20% MVC isometric contractions

Muscle	Variable	Perason's correlation analysis		CG (n=10)	DG (n=9)	NG (n=10)	ANOVA	
		r	P				F	P
TA	ISICoV (%)	-0.273	0.088	33.8±10.4[a]	26.5±6.5	26.0±6.9[a]	3.54	0.039*
	Median AUC (mV.ms)	0.452	0.003*	0.18±0.04[b]	0.30±0.06	0.33±0.17[b]	5.12	0.011*
	Maximal AUC (mV.ms)	0.243	0.130	0.25±0.08[c,d]	0.58±0.27[c]	0.53±0.32[d]	5.54	0.008*
	CC	0.392	0.012*	0.067±0.046[e,f]	0.183±0.064[e]	0.185±0.075[f]	11.73	<0.001*
				CG (n=6)	DG (n=5)	NG (n=13)		
GM	ISICoV (%)	0.469	0.021*	40.3±10.0	30.0±15.0	27.3±8.4	3.31	0.055
	Median AUC (mV.ms)	0.018	0.933	0.09±0.03	0.17±0.13	0.11±0.04	2.25	0.131
	Maximal AUC (mV.ms)	0.115	0.702	0.13±0.04	0.27±0.22	0.17±0.06	2.37	0.118
	CC	0.504	0.012*	0.041±0.027[g]	0.121±0.109	0.136±0.061[g]	4.17	0.030*
				CG (n=5)	DG (n=6)	NG (n=10)		
VL	ISICoV (%)	0.101	0.615	33.9±10.1	30.2±8.0	30.8±9.8	0.22	0.802
	Median AUC (mV.ms)	0.368	0.059	0.12±0.03	0.13±0.03	0.17±0.07	2.03	0.154
	Maximal AUC (mV.ms)	0.255	0.198	0.19±0.09	0.28±0.17	0.30±0.15	0.49	0.397
	CC	0.499	0.008*	0.018±0.032[h]	0.06±0.034	0.079±0.045[h]	4.22	0.027*

*Represents statistically significant difference; [a,b,c,d,e,f,g,h] represent difference between groups.

PI.35 Evaluation of recovery of lumbopelvic movement and motor control of individuals with nonspecific LBP using repeated forward bending task

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Introduction: Impaired movement kinematics and coordination of lumbopelvic movements have been consistently reported in individuals with low back pain (LBP). However, knowledge on the changes and capacity to regulate their movement and motor control of the lumbopelvic region during their recovery phase remains limited. This project examined the overall mobility, velocity and muscle recruitment strategy during forward bending task to better comprehend the modification of movement pattern and motor reorganisation of the lumbo-pelvic region in people with chronic nonspecific LBP.

METHODS: 30 adults (15 with nonspecific LBP [LBP] and 15 age- and gender-matched healthy controls [Healthy]) participated in this project. Three-dimensional kinematics of the lumbar spine and hip joints and surface electromyography (EMG) of the spinal and lower limb muscles were acquired during the execution of 7 cycles of repeated forward bending performed at their self-preferred speed at baseline assessment. Participants in LBP group then underwent a 6-week physiotherapy exercise program with emphasis on motor control training for the trunk core and hip region (twice/week for 6 weeks) followed by the reassessment using the same protocol. The overall mobility, mean velocity and EMG (in percentage of maximal voluntary isometric contraction, %MVIC) were compared at baseline between the two groups. These variables were also compared within LBP group before and after the exercise program.

RESULTS: At baseline, the sum of flexion mobility available at lumbar spine and both hips was comparable between two groups (211º in Healthy group and 209º in LBP group, $p>0.05$). In contrary, significantly longer time was taken to complete 7 cycles of bending task and significantly lower mean velocity at both lumbar spine and hip joints displayed in LBP group compared to Healthy group (Fig. 1 & 2). However, no significant differences were found in EMG amplitude (%MVIC) except the LBP group recruited significantly higher level of activity over left biceps femoris at baseline, provided that there were significant differences in mean velocity performance at both the lumbar spine and hip joints between two groups (Fig. 3a&b). At post-treatment reassessment, significant improvements in the 7-cycle task time, mean velocity and recruitment of the selective spinal muscles (lumbar erector spinae and lumbar multifidus) and hip extensors were shown in LBP group when repeated forward bending task was re-examined (Fig. 1-3a&b).

CONCLUSION: The present findings revealed improvements in the mean velocity and optimisation of motor control in terms of the reorganisations of muscle recruitment at the lumbopelvic region in people with nonspecific LBP in response to a 6-week physiotherapy exercise program. LBP group demonstrated the capacity to recover to a comparable level as in healthy controls using an evaluation approach which examines their dynamic and functional performance.

Fig. 1. Time required for completing 7 repeated cycles of forward bending task

* significant different between healthy & LBP pre- (baseline difference)
§ significant different between LBP pre- & post- (intervention effect)

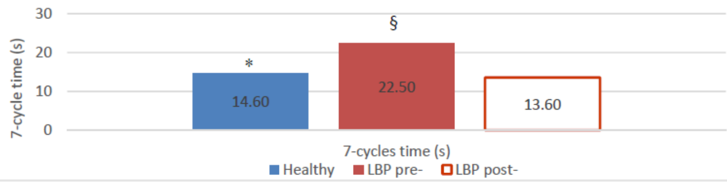


Fig. 2. Mean velocity at lumbar spine and hip joints during forward bending

* significant different between healthy & LBP pre- (baseline difference)
§ significant different between LBP pre- & post- (intervention effect)

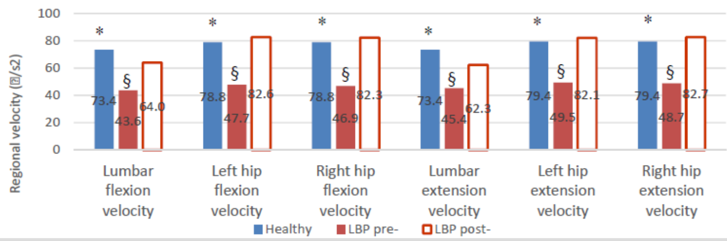


Fig. 3a. Comparison of muscle activation during flexion phase of forward bending

* significant different between healthy & LBP pre- (baseline difference)
§ significant different between LBP pre- & post- (intervention effect)

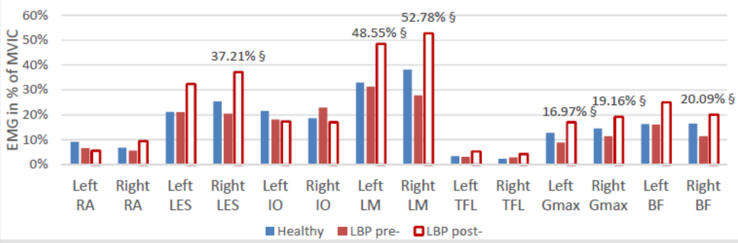
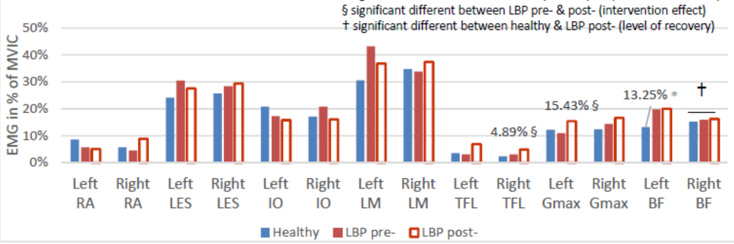


Fig. 3b. Comparison of muscle activation during extension phase of forward bending

* significant different between healthy & LBP pre- (baseline difference)
§ significant different between LBP pre- & post- (intervention effect)
† significant different between healthy & LBP post- (level of recovery)



PI.36 The Effects of Virtual and Traditional Golf Programs on Balance During Golf Swing in Chilren With Cerebral Palsy

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BACKGROUND AND AIM: Children with cerebral palsy (CP) have motor problems which effects their movement functionality. This generates the requirement of attending to a lifelong rehabilitation program. These programs become boring over time and causes sustainability problems. Because of this experts have begun to search for new enjoyable therapy methods. Sports and virtual reality have been used as alternative therapy methods in children with physical disability. The aim of this study wasto compare the effects of virtual and traditional golf programs on static and dynamic balance in children with CP.

Methods: Nineteen children with hemiplegic CP between ages of 6-12 (Gross Motor Function Classification System Level 1 and 2) participated in the study. Subjects were divided into two groups: virtual golf training (VG) (n=9, age: 8,22±1,71, height: 126,86±10,02, body weight: 26,64±5,65) and traditional golf training (TG) (n=10, age: 8,50±2,50, height: 125,85±12,17, body weight: 28,25±8,22). All children attended to full swing golf training program for 60 minutes a day, 3 days a week during the 12 week period. Static and dynamic balance were assessed with MatScan® force platform. COF area, distance, A-P and M-L sways were evaluated. Dynamic balance was also analysed using the changes in COF area, distance, A-P and M-L sway parameters during the full swing (backswing, downswing and follow through).

RESULTS: COF area and A-P sway decreased more in VG compared to TG on eyes open static balance ($p<0.05$). Although it was not improved significantly, weight distribuition between feet became nearly similar in both groups. No significant differences were found in dynamic balance parameters between two groups ($p>0,05$). It was reported that balance is controlled dominantly by motor cortex and motor planning is controlled by the left hemisphere. The fact that more right side effected hemiplegic children included in the virtual golf group, may be the reason of difference in improvement of balance ability between groups. At the same time, the objective of traditional golf is to hit the ball, therefore movement angle and direction is fixed. Whereas in virtual golf training any accuracy to hit the ball is not required.As a result expected to be higher. This difference in practice was thought to be the reason for the increased balance in VG. Weight distribution between feet found nearly similar between both groups. Higher weight distribution toward the effected foot, which has motor control problems, may be the reason for no improvement in COF parameters. Although there was no significant difference in dynamic balance, all children increased their swing speed. Similar COF values with the increased swing speed may show the positive changes in dynamic balance.

CONCLUSIONS: Virtual and traditional golf training methods improved postural control and increased the percentage of using affected extremity in children with hemiplegia. Future researches should examine how long these positive effects can be maintained, long term effects of golf training and sustainability of golf in children with CP.

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PI.37 Inter-limb coordination of redundant muscle activation was modularly regulated in shared bimanual reaching tasks

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INTRODUCTION: Human can control bimanual limb movements in cooperation with each other, such as balancing a laden tray held with both hands. Previous research demonstrated coordinated corrective response in the bimanual motor system during shared bimanual motor tasks (Diedrichsen, 2007). In unilateral tasks, a wide range of muscle activity was represented by a few functional modules, so-called muscle synergies, indicating the modular controller in the unilateral musculoskeletal system (Tresch et al. 1999; Hagio & Kouzaki, 2014). We hypothesized that robust inter-limb modules coordinate redundant muscle activation in both hands. To test the hypothesis, we examined the regulation of bimanual muscle activation during adaptation to a unilateral force field in shared bimanual reaching tasks based on the concept of muscle synergies.

Methods: The participants performed horizontal reaching movements holding robotic handles by their both hands. They sat in an adjustable chair to which their trunk was strapped. They were instructed to move a cursor presented at the spatial average position of the two hands from a start position located at approximately 40 cm in front of their body to one of the 8 equally placed targets by 45° on a horizontal display, as straight as possible. For the training, the participants performed reaching movements under the presence of a velocity-dependent curl force field only in the right hand (Shadmehr & Mussa-Ivaldi, 1994; Diedrichsen, 2007). To equalize the endpoint kinematics, we randomly used the error-clamp trials, with which the movement trajectory of the handle was constrained to a straight path from the start position to the target by a virtual force-channel (Scheidt et al. 2000). The experimental tasks were composed of 128 null field, 512 force field (FF) and 160 washout trials. During the tasks, surface electromyograms (EMGs) were recorded from 7 muscles spanning elbow and shoulder joints in both hands (14 muscles in total). Bimanual muscle synergies were extracted from the EMGs in error-clamp trials before the training using a decomposing technique.

RESULTS AND DISCUSSION: The lateral deviations of the cursor due to the unilateral force field were exponentially reduced and stable approximately one third in the FF trials. In the initial null field trials, at least 3 bimanual muscle synergies were needed across each participant. During training, the muscle activation was modified not only in right arm but also in left arm that was not exposed to a force field. The modified muscle activation early in the training was adequately reconstructed by bimanual muscle synergies before the training, whereas the reconstruction was inadequate late in the training. These results indicate that the spatiotemporal pattern of inter-limb coordination was modified depending on the inter-limb modules used before the training. The results provided evidence about the robustness of shared controller in both hands to control shared bimanual tasks.

MOTOR DISORDERS & NEURPHYSIOLOGY

PI.38 Impact of Malocclusion on the Masseter and Temporalis Muscles of Children

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BACKGROUND AND AIM: The malocclusion promotes changes in the stomatognathic system. This study evaluated the electromyographic activity (sEMG) in children without and with orthodontic treatment needs.

METHODS: The Dental Health Component of the Index of Orthodontic Treatment (IOTN-DHC) was used to classify malocclusions. Ninety children were evaluated and distributed into three groups: Group I (no need for orthodontic treatment; mean ± SD 8.0 ± 0.4 years; 26 children), Group II (little malocclusion with need for orthodontic treatment; mean ± SD 8.8 ± 0.4 years; 28 children) and Group III (moderate malocclusion with need for orthodontic treatment; mean ± SD 8.4 ± 0.2 years; 36 children). Delsys Trigno EMG Systems wireless was used to evaluate the right masseter (RM), left masseter (LM), right temporal (RT), left temporal (LT) and orbicular oris muscles in the: jaw rest condition (4 s), dental clenching in maximal voluntary contraction with (4 s) and without Parafilm M® (4 s); right laterality (5 s), left laterality (5 s) and protrusion (5 s). The electromyographic normalized data were submitted to statistical analysis (SPSS; ANOVA and Bonferroni post hoc test), $P < 0.05$. This study was previously approved by the Research Ethics Committee of Ribeirão Preto Dental School, University of São Paulo, Brazil.

RESULTS: sEMG in almost all jaw postural conditions were higher in Group III with statistically significant differences for the rest: right masseter ($P = 0.03$) and protrusion: left temporal ($P = 0.02$).

CONCLUSION: Children with moderate need for orthodontic treatment have functional alterations in the masticatory muscles. ACKNOWLEDGEMENT: CNPq and FAPESP (2015/09942-4)

PI.39 The Effects Head/Neck Injury on Motor-neuron Reflex Excitability, Motor Preparation and Reaction Time: A Pilot Study

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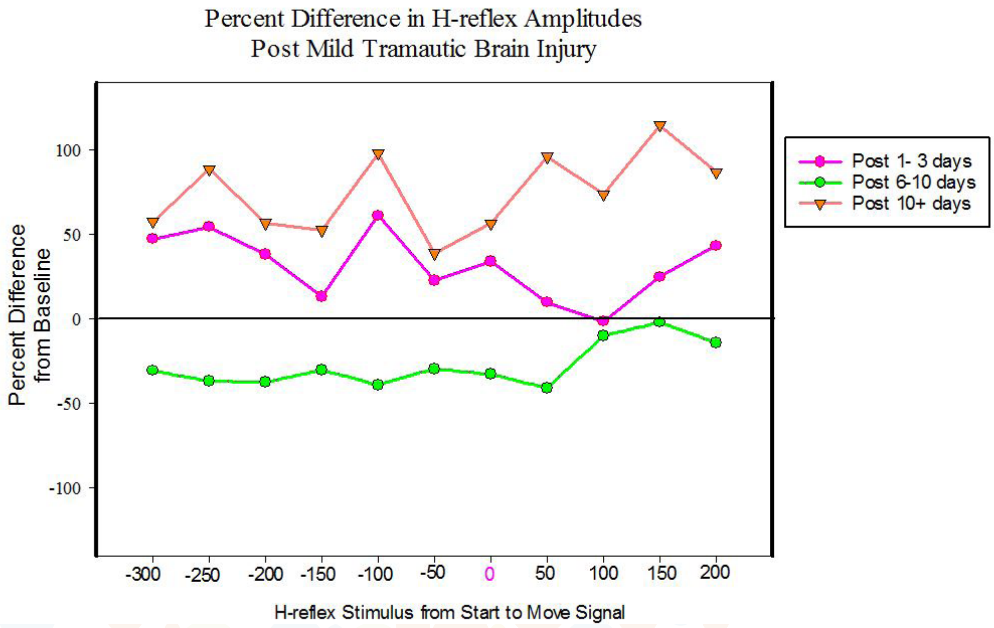
BACKGROUND AND AIM: Persons who participate in high impact sports are prone to concussive injuries. When a concussion is suspected, an athlete is screened to assess the severity of the injury. These tests mainly target cognitive function and only minimally assess the motor system. Testing the motor system is important for athletes whose performance and safety rely heavily on motor control and response time. The purposes of this study were to assess the effect that a head injury has on 1)spinal motor neuron reflex excitability (MNRE), 2) spinal motor neuron excitability levels over time when preparing for a volitional movement (Motor Preparation) and 3) reaction time (RT).

METHODS: Severity of Head injury was determined by comparing IMPACT and SCAT3 testing results before and after injury. MNRE was assessed using the standardized Soleus H-reflex technique. Motor preparation (MP) was evaluated by randomly eliciting a series of H-reflexes before and after a Start to Move signal was given to the participant. H-reflexes were evoked from 300ms before to 200ms after the movement initiation signal at 50ms intervals. Three H-reflexes were evoked for each of the time intervals and averaged. RT was measured from the random Start to Move signal to the initiation of movement. The beginning of movement was determined from a deflection on an oscilloscope when the participant pressed against a force transducer. H-reflexes were elicited at 15-25% of Mmax, amplified 1000X and digitized at a sampling frequency of 5000Hz at a bandwidth of 3Hz - 10,000Hz. Seventy participants were baseline tested. Post injury experiments were conducted before injury and at three separate times, 1-3, 6-10 and 10+ days post injury. Only, five participants returned for all three post injury testing. Data analysis was conducted on these five data sets. All results were plotted and compared with baseline data. Descriptive statistics were used to detect change due to the small sample size.

RESULTS: MNRE and RT showed no difference compared with base line values for the three post-injury testing sessions. MP results showed a moderate to large facilitation across all H-reflex amplitudes intervals from 25-100% above baseline values. This facilitation was seen for the 1-3 and 10+ day post injury testing dates. For the 6-10 day testing session, MP was substantially depressed (~25%) for all intervals before and after the initiation of movement. The 150ms post movement time was the only exception. Interestingly, this 25% depression was observed for every pre-movement initiation interval. This flat depressive response was not characteristic of the normal response observed at baseline testing. There is usually a descending facilitation superimposed onto the underlining inhibition peaking at 100ms prior to movement initiation. The characteristic response was observed for all 70 baseline participants tested.

CONCLUSION: These preliminary results suggests that head injury may have a negative effect on the normal development of motor neuron excitability in preparation for volitional movement at the 6-10 day post injury dates. Since MNRE was not effected in these individuals, results suggest that the change in MP has a supraspinal origin.

RESULTS of this study suggests further study in needed to determine what the functional outcome our results may impose on sports performance.


Percent Difference in H-reflex Amplitudes
Post Mild Tramautic Brain Injury
Percent Difference from Baseline
100
50
0
-50
-100
-300
-250
-200
-150
-100
-50
0
50
100
150
200
H-reflex Stimulus from Start to Move Signal
Post 1- 3 days
Post 6-10 days
Post 10+ days

PI.40 Regularity of force control in participants with and without spastic Cerebral Palsy during isometric contractions of the elbow joint

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BACKGROUND AND AIM: The links between spastic Cerebral Palsy (sCP) and progressive secondary musculoskeletal problems including muscle weakness and poor motor control are not well understood [1]. Improved insight into force control strategies could have promising implications for CP management. One aspect of motor control can be assessed by the sample entropy, indicating the regularity of the force [2]. This pilot study aims to investigate the force regularity in participants with and without sCP.

METHODS: Twelve participants without sCP (3F/9M; mean age: 22.09y, range: 6y-36y) and five participants with sCP (3F/2M; mean age 14y, range: 5y-31y; GMFCS III: 1, GMFCS IV: 2, GMFCS N/A: 2) were recruited for the study. The groups were not age or gender-matched. Participants performed two maximum strength tests for the elbow flexors with an angle of 80°. Subsequently, isometric force ramps were performed twice with real-time visual feedback of target and current force levels displayed on a computer screen. Each force ramp consisted of an increasing, plateau and decreasing phase. The ramp- and plateau-phases lasted for 7.5s and 10s, respectively for all conditions. The force plateau was scaled to 15% (FRL), 30% (FRM) and 70% (FRH) of the participants' individual maximum elbow flexion strength, amounting to six force ramps performed in total. The force regularity in each phase was evaluated by computing sample entropy of the force signal, using an embedding dimension of 2 and a tolerance distance of 0.2 x SD of the corresponding force signal subsets [2]. Statistical differences between groups were evaluated using the Mann-Whitney U test.

RESULTS: As can be seen in Figure 1, the sample entropy for the FRM and FRH during the plateau phase was significantly lower in those with CP (median difference: -0.0328, $p = 0.018$ and -.0706, $p = 0.031$, respectively). In contrast, the force regularity for the FRL and FRM during the increasing and decreasing phase was significantly higher in the control group (increasing med. dif.: 0.006, $p = 0.019$ and 0.010, $p = 0.048$; decreasing med. dif.: 0.012, $p = 0.013$ and 0.004, $p = 0.031$, respectively).

CONCLUSIONS: This study gives the first insights into possible differences of the structure of force-variability in sCP. The force regularity during the increasing and decreasing phases of a force ramp protocol was higher in the control group. Interestingly and contrary to expectations, the force regularity during constant isometric contractions was significantly larger in individuals with CP. This lower structure of force variability might lead to an increased risk of injuries during sustained contractions [2]. Further studies should aim to recruit age and gender-matched groups to evaluate muscle force control for different subtypes of CP.

[1] Stackhouse et al. Muscle Nerve, 31(5): 594-601, 2005. [2] Svendsen and Madeleine, Hum Mov Sci, 29(1): 35-47, 2010.

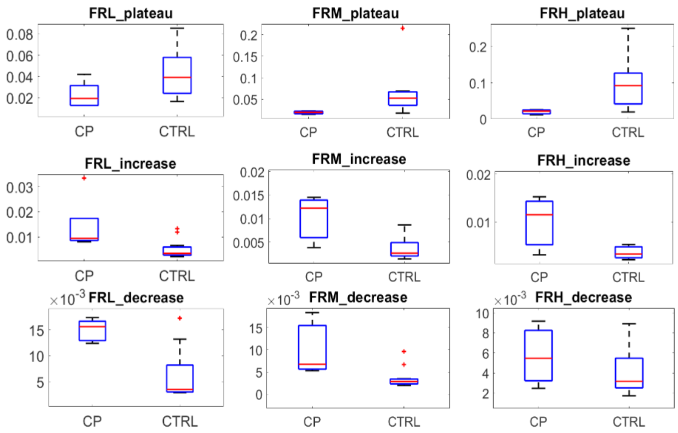

Figure 1: The sample entropy for each force ramp (FRL: Force ramp low; FRM: Force ramp medium; FRH: Force ramp high), phase (plateau, increasing and decreasing phase) and group (CP: Cerebral Palsy; CTRL: Control) are visualized using boxplots. Please note that a larger value for sample entropy indicates a lower force regularity.

PI.41 Effect of different pre-processing methods on somatosensory evoked potentials.

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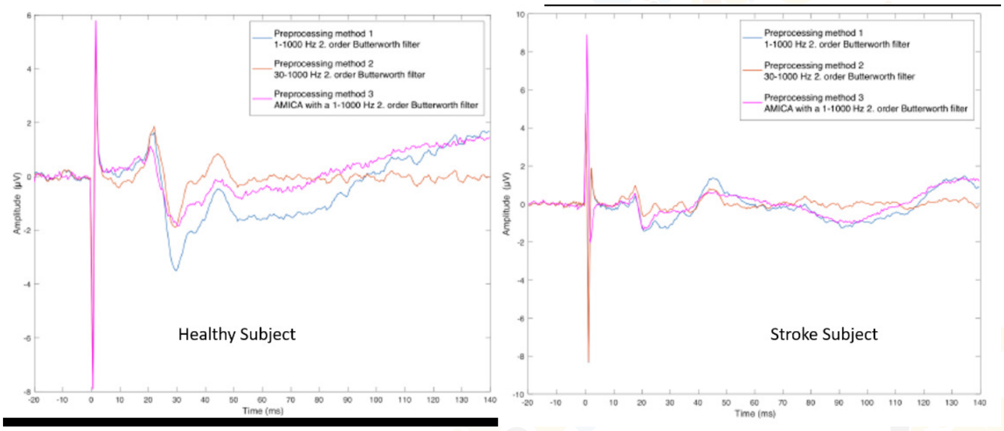
BACKGROUND AND AIM: Several pre-processing methods are used in literature to pre-process somatosensory evoked potentials (SEPs) signals. However, there is no agreed-upon standardized way of performing pre-processing for SEPs. This lead to an investigation of whether there is a difference in the measure of amplitude and latency of P22 and N30 peak in SEPs of healthy and stroke patients using different pre-processing methods which are frequently used in literature.

METHODS: 183 datasets from 31 volunteers were included in the study from 17 healthy (mean age 27.33±5.57) and 14 stroke patients (mean age 50.64±12.54 years). During the EEG recording, SEPs were evoked by applying electrical stimulation through stimulation electrodes on the median nerve of all participants. After literature survey on PubMed (Articles published articles beyond the year 2000 were used) following pre-processing methods were chosen to calculate amplitude and latency of P22 and N30 peak: (1) 1-1000 Hz, 2nd order Butterworth filter, (2) 30-1000 Hz 2nd order Butterworth filter, and (3) an Adaptive Mixture Independent Component Analysis (AMICA) with a 1-1000 Hz, 2nd order Butterworth filter on SEPs for healthy and stroke subjects. To avoid potential bias, the analysis was carried blindly. All the label whether a given set of data belongs to stroke or the healthy patient was removed. Statistical analysis was carried post blinded data.

RESULTS: Post blinded data analysis revealed that data was not normally distributed so non-parametric statistics were carried. The results showed no significant difference in the latency of P22 and N30 peaks for any of the three pre-processing methods on both healthy and stroke subjects. But the amplitude of P22 and N30 peaks differed significantly when different pre-processing methods were used.

CONCLUSIONS: In conclusion, different pre-processing commonly used in literature for stroke or healthy subjects resulted in a statistically significant effect on the amplitude. This implies that there is a need for a standardized method for pre-processing SEP's data to make results from different studies comparable to each other.



PI.42 Upper limb recovery in aphasic patients after vascular accident: a theory.

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Cortex and cortical function can be regarded as modular, with separate areas involved in processing sensory information and the initiation of motor movement. The blood supply supporting cortex is, like the brain itself, modular. Disruption in blood flow leads to a multiplicity of dysfunctions like the frequent co-occurrence of aphasia and right upper limb hemiparesis. A review of the vascular accident literature reveals a correlation between Broca's aphasia and upper limb motor recovery. The precise reason for the correlation is not known but this paper proposes one. Patients with Broca's aphasia show slower and poorer motor recovery of right arm compared to non-aphasic ones. Different causes were summoned to explain the difference in recovery. Our theory, contrary to other conclusions, is that speech impairment is indicative of damage to Brodmann area BA45 but that the motor deficits are due to damage to the proximal, but functionally discrete area BA44. BA44 is a multi sensory area. But experiments on tone-deaf or stutters, radiological tools like f MRI and DWI, studies of the neuro-ontogeny and development in babies, findings of genetic, epigenetic and embryology, all point to BA44 playing a central role in visuo-motor integration.

PI.43 Sensory, Visual Spatial, and Motor Planning Activity Supports Motor Cortex Efficiency After Neuromuscular Training

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[1]Ohio University, [2]Cincinnati Childrens Hospital Medical Center, [3]University of Cincinnati, [4]George Mason University, [5]University of Groningen

BACKGROUND AND AIM: Neuromuscular training (NMT) for musculoskeletal injury prevention improves sensorimotor coordination and reduces movements that increase injury-risk. However, the specific neural changes associated with NMT are unknown. This has limited the development of evidence-based NMT that targets the neural mechanisms of knee motor control. The purpose of this study was to determine knee motor control neuroplasticity associated with NMT.

METHODS: Twenty high school female soccer athletes participated in the study (15.7±1.0 years; 1.7±0.05 m; 59.9±5.6 kg). Ten of the 20 participants completed 6 weeks of NMT with augmented biofeedback. The remaining 10 participants did not complete NMT and served as controls. The NMT was augmented with the implementation of visual biofeedback (a rectangle projected on a screen in front of the participant) that deformed in real-time as a function of targeted injury-risk biomechanical variables during exercise. Participants viewed and controlled the stimulus to elicit desirable movement mechanics associated with reduced injury risk. Pre-post brain activation changes were measured using functional magnetic resonance imaging (fMRI) during a unilateral leg positioning task consisting of knee extension and flexion, and a loaded leg-press task consisting of hip and knee flexion and extension, to determine knee motor control neuroplasticity.

RESULTS: Sensory (precuneus and parietal cortex, voxels: 964; $p<.001$; z-max: 3.38; peak voxel coordinate: 18, -68, 46), visual-spatial (lingual gyrus and supracalcarine cortex, voxels: 461; $p=.023$; z-max: 3.33; peak voxel coordinate: 24, -64, 12) and motor planning (pre-motor cortex, voxels: 416; $p=.040$; z-max: 3.40; peak voxel coordinate: 60, 4, 34) brain activity was increased for leg positioning after neuromuscular training. This network of increased brain activity was correlated ($r=.87$, $p=.001$) with decreased motor cortex activity (voxels: 380; $p<.001$; z-max: 6.88; coordinate peak voxel: 6, -34, 80) for the loaded leg-press post-training. No significant change in brain activity was observed in the controls between pre- and post-assessments.

CONCLUSIONS: Increased sensory, visual-spatial, and motor planning brain activity following NMT may facilitate more efficient (i.e., decreased) primary motor cortex activity during loaded conditions. The neural changes observed suggest that NMT facilitates recruitment of neural support to control knee position and improve neuromechanical efficiency. Further research is warranted to determine if the multidimensional neuroplasticity revealed during unloaded and loaded tasks transfers to more complex landing and cutting activities providing a potential mechanism for improved adaptive responses to NMT.

PI.44 Muscle-tendon Units Localization and Activation Level Analysis based on High-Density Surface EMG signals

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BACKGROUND AND AIM: Some skeletal muscles can be subdivided into smaller segments called muscle-tendon units (MTUs). Although within one muscle, different MTUs may show different activation levels as the angles of some related joints change when a movement task is performed. In this study, a non-negative matrix factorization (NMF) algorithm was applied to high-density (HD) surface electromyogram (sEMG) signals obtained from a single skeleton muscle to investigate the heterogeneity of muscle activation, which could help locate MTUs and show their activation levels.

METHODS: The HD sEMG envelope matrix was factorized by the NMF algorithm to get a matrix of basis vectors with each column representing an activation pattern and a matrix of their corresponding time varying coefficients. The area of each MTU was identified through a gray-scale map of weighting factors derived from its activation pattern vector. In order to verify the feasibility of the proposed method, an arm related motion task was defined in our study. Four healthy subjects participated in the experiment, and 64-channel sEMG signals were collected with a HD sEMG electrode grid (a grid consists of 4 rows and 16 columns) from the biceps brachii of each subject. Before the task, the angle between the arm and the body of each subject was near 0 degree. During the task, each subject was instructed to keep contracting the biceps brachii muscle to perform elbow flexion and meanwhile the staff slowly moved the upper arm of the subject away from the body until the angle between the arm and the body reached about 45 to 60 degrees, and then slowly moved the arm back to the original position. It was hypothesized the task involved two main activation patterns, one representing that the lateral head was preferentially activated and the other representing that the medial head was preferentially activated.

RESULTS: The results showed that specific distinguishable area of MTUs could be identified through the extracted activation patterns and their corresponding time-varying coefficient curves could efficiently depict how the activation level of each MTU changes through the task performance.

CONCLUSIONS: The advantage of the method is that the factorized result of NMF is quite robust and insensitive to noise, whereas the results of root mean squares (RMS) method is sensitive to the length of the window and influenced significantly by the noise. The method can be employed on multiple noteworthy sEMG-based applications such as muscle force estimation, muscle fatigue research and the control of myoelectric prostheses.

MOTOR PERFORMANCE & SPORTS SCIENCE

PI.45 The impact of vibration on shoulder muscle activity: An EMG study

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Introduction: Whole body vibration (WBV) is known to increase muscular activity when used to supplement exercises due to the tonic vibration reflex. This beneficial effect however has predominantly been demonstrated in the lower limb. There is only a paucity of evidence addressing the upper limb, with no work previously focusing on the rotator cuff muscles. Defining the impact of WBV and vibration applied locally through the upper limb (arm vibration (AV)) on shoulder muscle activity would guide exercise physiologists and rehabilitationists in implementing evidence based practice. The primary aim of this work was therefore to study the effect of vibration (WBV and AV) on the activity of shoulder girdle muscles. The hypothesis was that increased activity levels would be seen with the addition of vibration to exercises.

METHODS: Twenty healthy participants enrolled. A Telemyo DTS system (Noraxon Inc., USA) was used for EMG signal acquisition and analysis was performed off-line using the associated MR3 software (Noraxon Inc., USA). The activity of 15 shoulder girdle muscles was studied including the supraspinatus, infraspinatus and subscapularis. EMG was recorded as subjects undertook an isometric contraction in forward flexion at 90o of shoulder elevation. The contraction was performed at 25% of their maximal voluntary contraction. Vibration was delivered using a vibrating platform and associated handle (Power Plate, Performance Health Systems). Three testing scenarios were employed: no vibration (NV) (subjects stood on Power Plate with system switched off); WBV (subjects stood on Power Plate with system switched on); and AV (vibration delivered though the handle of Power Plate but subjects not stood on platform). Three trials were performed in each testing scenarios and the average taken. EMG signals were processed in accordance with ISEK standards. Repeated measures analysis of variance was used to compare the mean amplitudes in each testing position.

RESULTS: Mean amplitude of the anterior deltoid was significantly higher with AV as compared to NV or WBV (37.9±3.2 vs 29.1±2.3% vs 33.6±2.2% respectively; $p=0.002$). Activity was significantly higher with WBV and AV as compared to NV for middle deltoid, posterior deltoid, upper trapezius, middle trapezius, lower trapezius, serratus anterior, latissimus dorsi, supraspinatus and infraspinatus ($p=<0.001$ - 0.027). There were no significant differences across the testing scenarios for pectoralis major, biceps brachii or subscapularis.

CONCLUSION: The addition of vibration to an isometric muscle contraction resulted in significantly higher activity levels in a number of the shoulder muscles. There was no significant difference between vibration applied locally through the arm and WBV for the majority of the muscles studied. This increased activity is due to the tonic vibration reflex. This work supplements the evidence based for exercise physiologists and rehabilitationists.

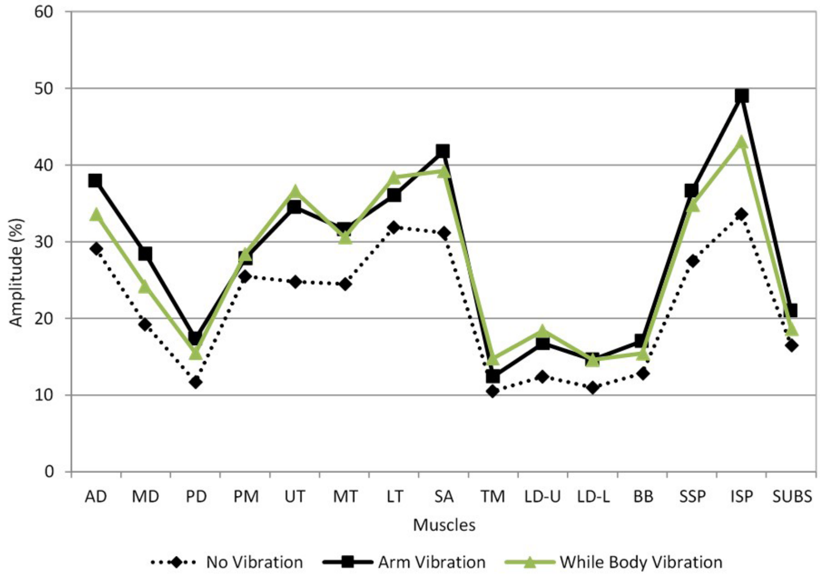

Figure. Muscle activity level in the three testing scenarios

PI.46 Functional connectivity of hand-arm muscles during a repetitive fatiguing task

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Aalborg University

BACKGROUND AND AIM: The pattern of load sharing has been suggested to be functionally relevant as the individuals with high variability in the load sharing pattern seem to show an increased endurance during fatiguing contractions. Indices of functional connectivity can potentially be used to delineate the load sharing pattern. For example, an increased normalized mutual information between muscles involved in the task has been reported as fatigue develops. Some of the indices of the functional connectivity are insensitive to the direction of the connection while some other such as Wiener-Granger causality (G-causality) are directed indices. A variable Y is defined as G-cause of a variable X (Y→X), if Y improves the prediction of the future of X beyond the prediction derived from the past of X. Thus, the aim of this study was to investigate directed functional connectivity, i.e., G-causality between hand and arm muscles during a fatiguing repetitive dynamic task.

METHODS: Nineteen right-handed females participated in the study where a pipetting task was used as a model of a repetitive dynamic task with high precision demand. The task was composed of cyclic moving of a hand-held pipette between a pickup tube (ø: 20 mm) and one of eight target tubes (ø: 6 mm), arranged in an array of 10×10 tubes of identical size. Surface bipolar electromyography (EMG) was recorded from the right biceps brachii (BB), the lateral head of the triceps brachii (TB), deltoideus anterior (DA), serratus anterior (SA), upper (UT) and lower trapezius (LT). A reference electrode was placed on the C7 vertebra. G-causality between all the muscles in pairs was obtained and the evolvement of the G-causality through the task timeline outlined in ten equi-distance segments.

RESULTS: The G-causality from DA to BB (DA→BB) and TB (DA→TB) changed across the timeline, particularly, DA→BB increased monotonically with time. No association was observed between the estimated G-causality in the first time segment and the time to task termination.

CONCLUSIONS: The directedness of G-causality from a proximal (DA) to a distal (BB) muscle may be indicative of the directional flow of mechanical energy in the movement pattern. In conclusion, G-causality seemed to be an informative index of the functional connectivity, which provides some insights to the pattern of load sharing between the involved muscles in a fatiguing task.

PI.47 Comparison of the etiology of neuromuscular fatigue among the lower limb muscles between boys and men.

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[1]AME2P Laboratory, Clermont-Auvergne University, FRANCE, [2]Clermont University Hospital

BACKGROUND AND AIM: The aim of the present study was to compare the development and etiology of neuromuscular fatigue after repeated maximal voluntary contractions performed with the knee extensor (KE) and plantar flexor (PF) muscles until a standardized level of exhaustion in children and adults. We hypothesized that the muscle group developing the higher absolute force level, i.e. KE, display a higher peripheral fatigue level and faster exhaustion as compared to muscles developping less strength, i.e. PF, for which the development of central fatigue should prevail. The same effect of the absolute force level would also account for the prevalence of peripheral fatigue and shorter exercise duration in adults, and of longer exercise duration in children, thereby promoting central fatigue.

METHODS: Twenty-one children (9-11 years) and 24 adults (18-30 years) were involved in this study. They performed a fatigue protocol with the KE and FP, consisting in repeating voluntary maximal contractions until reaching 60% of the initial torque. Magnetic nerve stimulations were delivered to quantify the maximal voluntary activation (VA) with the twitch interpolation technique. Potentiated twitch amplitude (twpot) was used as a general indicator of peripheral fatigue. M-wave amplitude and low to high frequency doublets ratio were measured to get insights into sarcolemmal excitability and excitation-contraction coupling, respectively.

RESULTS: The number of contractions performed with the KE muscles was greater in children than adults (38.7 ± 18.8 vs. 15.4 ± 3.8 repetitions, $P<0.001$, respectively). Conversely, a comparable number of repetitions was observed between both groups on the PF muscles (12.1 ± 4.9 vs. 13.8 ± 4.9 repetitions for children and adults, respectively). A significant interaction of muscle group x age group was found for twpot. Twpot decrease was significantly greater in adults than children for both muscle groups ($P<0.05$), and in KE than PF for both age groups ($P<0.05$) (KEadult: : -47.7 ± 17.2%; KEchild: -14.6 ± 18.1%; FPadult: -24.0 ± 16.7% ; FPchild: -10.2 ± 10.7%). Similarly, the low to high frequency ratio decreased to a higher extent in adults than children, and in KE than PF. Conversely, no decrease of the M-wave was observed for any age group or muscle group. Finally, VA decreased significantly less in adults than children for both muscle groups ($P<0.01$). In addition, VA decreased significantly more in KE than PF in children ($P<0.01$), while no significant difference was observed between both muscle groups in adults (KEadult: : -6.0 ± 6.6%; KEchild: -39.7 ± 21.8%; FPadult: -13.0 ± 10.3% ; FPchild: -
28.7 ± 15.4%).

CONCLUSIONS: To conclude, differences in fatigability between children and adults are dependent on muscle groups investigated. While children fatigue less than adults for KE, they experience similar fatigue for PF. However, adults systematically experience more peripheral and less central fatigue than children, whatever the muscle group investigated.

PI.48 Surya Namaskar Practice on Body Weight, Body Mass Index, and Body Fat in Obese Females: A Case Study

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Introduction: Surya namaskar, also called sun salutation can use practice for health, fitness, and long life are some part of traditional Indian. Which, surya namaskar is a physical activity that involves almost every body part and it is a great form of exercise. At present, many surya namaskar practitioners believe that the practice leads to reduce body weight, body mass index, and body fat. Therefore, the objective of this case study was to examine the effects of surya namaskar practice on body weight, body mass index, and body fat in obese females.

Methods: Ten obese female from staffs of Nakhon Ratchasima College, Nakhon Ratchasima, Thailand were participants in this study (age 38.10±1.66 yrs, high 158.10±3.21 cm, and body weight 66.35±3.48 kg). All participants were tested for body weight on a digital platform scale, body mass index was calculated by dividing weight with squared high, and calculating body using four skinfold measurements in biceps, triceps, subscapular, and suprailiac sites prior to starting an eight-week surya namaskar practice. The participants then completed an eight-week surya namaskar practice were retested.

Results: The results of this study show that no significant differences between pre- and post-test of an eight-week surya namaskar practice on body weight (66.35±3.48 and 65.90±2.99 kg; $p \geq 0.06$), body mass index (26.58±1.20 and 26.40±0.98 kg/m2; $p \geq 0.06$), and body fat (33.31±2.49 and 33.03±2.36 %; $p \geq 0.83$).

Discussion: A recent study has found that surya namaskar practices were good on body composition in obese persons. However, this case study not supported in the past of study. The findings of this study suggested that three days a week of an eight-weeks surya namaskar practice was not sufficient enough to show significant differences in body weight, body mass index, and body fat in obese females.

PI.49 An investigation of the EMGs spatial distribution on pectoralis major during flat and inclined bench press

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AIM: The pectoralis major (PM) muscle fibres have a varied orientation along its length, with their arrangement resembling a fan [1]. Due to this unique muscle architecture, the PM is divided in clavicular region (a small area closer to the clavicle) and sternal region (the majority part of PM fibres). Based on previous evidence, suggesting the clavicular region would be more activated during the inclined bench press exercise [2], here we investigate whether the surface electromyograms (EMGs) distribution of PM muscle change with the increase in bench press inclination. Placing a liner array of electrodes transversally to PM fibres and away from innervation zone (IZ), we expect to observe a shift of the EMGs barycentre coordinate towards to clavicular region with the increase of the bench press inclination.

METHODS: Five healthy, male subjects (mean ± SD: 27.2 ± 5.0 years; 174.2 ± 7.8 cm; 77.5 ± 5.4 kg) were recruited. The participants were instructed to perform 1 set of 15 repetitions using a 50% of 1 maximal repetition load for both exercise conditions: (i) flat bench press; (ii) inclined bench press at 45 deg. The order of bench press exercises was randomized and the movement velocity was controlled with metronome (2s each movement phase). The barbell should gently touch the muscle and the grip distance was defined as 200% of biacromial distance. An array of 16 electrodes (10 mm IED) perpendicularly positioned to PM fibres was used to sample EMGs. The adhesive array was medially placed from the IZ of PM (previously identified) and covering the entire cranio-caudal axis. The RMS values of EMGs were computed for each of differential channel and separately for each movement phase (concentric and eccentric). From these values, the active channels were calculated (i.e., EMGs amplitude greater than 70% of the maximal amplitude; [3]). The barycentre coordinate of the RMS distribution along PM cranial-caudal axis was then obtained, separately for each movement phase and exercise condition. The ANOVA two-way test was applied to compare the barycentre coordination position between the two exercise conditions (flat and inclined bench press) and along all repetitions (15 repetitions divided in eccentric and concentric phases).

RESULTS: When compared the flat and inclined bench press, the barycentre coordinate significantly changed for all repetitions ($P < 0.0001$ for all cases). Specifically, the EMGs amplitude distribution shifted towards to PM cranial direction with the bench press inclination. Otherwise, within the same exercise condition, the barycentre coordinate did not change along repetitions.

CONCLUSION: Our results suggest a localised distribution of the EMGs amplitude on the PM muscle during the bench press exercise. Furthermore, our findings indicate that the PM clavicular region is indeed more demanded during the inclined bench press when compared with the flat bench press exercise.

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PI.50 Performance Evaluation on Endoscopic Tasks from Forearms EMG signals within High Trained Surgeons

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BACKGROUND AND AIM: The authors supported a simulator contest of endoscopic performance in the 28th Annual Meeting of the Japan Society for Endoscopic Surgery and recorded multi-channel surface EMG signals during endoscopic tasks of surgeons who entried the contest. Thirty three male physicians were high-quality trained endoscopic surgeons in Japan. The authors tried to record multi-channel surface EMG signals during laparoscopic tasks with Myo Armband which was produced by Thalmic Labs Inc., Canada. The Myo Armband system is a small size and can measure 8-channel surface EMG, 3-axis gyroscope, accelerometer and magnetic orientation signals around arms. They tried six times knot-tying tasks in the box with two Kocher forceps within a few minutes. The duration that six time tasks completed is 48.4±18.1s. Then, they were wearing the Myo Armband systems on both their forearms and recorded their 8-channel EMG signals during the tasks. All the EMG signals were recorded with sampling frequency 200Hz and resolution 8bit.

METHODS: The authors supported the simulator contest competing for endoscopic technique in the 28th Annual Meeting of the Japan Society for Endoscopic Surgery. In the contest, multi-channel surface EMG signals during endoscopic tasks of surgeons who entried the contest were recorded. All of thirty three physicians were high-quality trained endoscopic surgeons in Japan. The authors tried to record multi-channel surface EMG signals with Myo Armband systems (Thalmic Labs, Canada) during six time knot-tying tasks in a training box which is one of tests in the contest. The Myo Armband system is a small size and light weight and can record 8-channel surface EMG, 3-axis gyroscope, accelerometer and magnetic orientation signals around arms simultaneously. The physicians tried the tasks with two Kocher forceps within several tens of seconds. The mean duration of all tasks completed is 48.4±18.1s (mean±SD). The physicians wore the Myo Armband systems on both their forearms and recorded EMG signals during tasks. All the EMG signals were recorded with sampling frequency 200Hz and resolution 8bit during the tasks.

RESULTS: The authors draw out channel #2 and #6 near extensor digitorum muscle and flexor carpi ulnaris muscle from the 8-channel surface EMG signals and then extracted relatively low and high frequency (40 and 70Hz) amplitude signals with complex demodulation (CDM) which is a kind of time-frequency domain analysis. Our past studies have already reported on previously indicated two channels to find the possibility to evaluate performance of endoscopic technique. The three statistics, variance, skewness and kurtosis, were calculated from the low and high frequency amplitude signals. At last, logistic regression with Keras on python language estimated a probability, which may present the performance, from the three statistics of subjects' EMG signals.

CONCLUSIONS: In conclusion, our results indicate that our technique may have the possibility to measure the performance of endoscopic technique based on statistics of multi-channel EMG signals.

PI.51 Kinematic and muscular response to impacts on the shoulder

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BACKGROUND AND AIM: Impacts on the shoulder can cause shoulder- and neck pain due to soft tissue damage and strain on the ligaments and tendons. Current guidelines to mitigate health risks are energy based and not measured in realistic conditions. Individual body characteristics, personal protective equipment and the intensity and rate at which the forces are applied to the shoulder should be accounted for in future regulations. Although this is an important issue for hunters and military personnel, there is currently no scientifically supported criterion with measurable thresholds. Most current impact- and crash models, related to the shoulder- and neck region are either passive and inertia driven or limited by the inherent difficulty of modelling and registering the shoulder joint kinematics. This study wanted to evaluate the validity of such models and recorded the kinematics of the shoulder-neck-head complex and the contact forces during intense, short impact loading on the shoulder. Furthermore we investigated the effect of firearm recoil on the activity of the shoulder- and neck muscles. The influences of repetitive impacts and wearing a helmet, and thus higher head inertia, were investigated.

METHODS: After a series of MVC-exercises, 19 subjects were asked to fire a series of single shots and automatic bursts and performed this routine with and without a helmet. Muscular activity of 14 muscles in the neck, shoulder and upper extremities were simultaneously recorded: Sternocleidomastoid (L+R), Splenius Capitis (L+R), Levator Scapulae (L+R), Upper Trapezius (L+R), Deltoid Posterior+Anterior (R), Serratus Anterior (R), Pectoralis Major (R), Biceps (R) and Triceps (R). Kinematics in the sagittal plane was tracked with high speed cameras (1000 fps) and contact forces were recorded at the interface with the rifle stock.

RESULTS: We first evaluated the effectiveness of 15 MVC-exercises based on their mean maximum value and standard deviation across all subjects. We showed redundancy in the proposed exercises in literature. The very short solicitation time of the shoulder (a few ms) during the trials imposed specific filter constants to prevent excessive smoothing of the EMG signals. Statistically significant differences in kinematics and muscular activity were observed before, during and after repetitive loading with respect to single impacts on the shoulder, illustrating bracing, anticipation and higher demands to maintain posture. As expected, the Levator Scapulae was the most active neck muscle as it is the only analyzed muscle connecting the head and the shoulder girdle. Wearing a helmet did not result in statistical significant differences on the registered EMG values but clearly showed smaller head displacements in comparison to the unhelmeted condition.

CONCLUSIONS: Our findings support the use of passive models for the initial reaction to impacts but underline the effects of muscle pre-tension and body characteristics.

PI.52 The effects of figure-ground reversal visual clue on the throwing performance of individuals with cerebral palsy

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BACKGROUND AND AIM: The ability of children with brain damage to organize stimuli into meaningful whole and to distinguish figure from ground are often impaired. The purpose of this study was to have a better understanding of how different visual clues affect the throwing performance of individuals with cerebral palsy (CP).

METHODS: Eight individuals with spastic CP (aged, 8-31 years) and 13 healthy adults (aged, 19-22 years) participated in this study. This research study was conducted with the approval of the Osaka Prefecture University research ethics committee (2016-103). The participants were asked to throw a beanbag underhand towards a circular target with a 1-m radius located 4 m away, from a seated position. Two different circular targets (a white circular target with a black central target of 20-cm radius, white grand target; and a black circular target of the same size with a white central target, black grand target) were prepared. The participants were randomly assigned to each circular target. After a 15-minute washout period, each participant threw the beanbag towards the circular target. Each task consisted of 30 throwing trials. The accuracy of throwing was judged by 2 examiners. The dropped area in each trial was assessed using concentric circles with radii of <20 cm (Excellent), 20 to 50 cm (Good), and 50 to 100 cm (Normal) drawn around the target. In addition, when the examiners were not in agreement, the dropped area was judged again using 3 iPhone video recordings for beanbag trajectory. To compare the sampled data, the Wilcoxon signed-rank test was used. The statistical significance was set at $p = 0.05$.

RESULTS: Among healthy adults, no significant difference in each assessment was observed, between the 2 targets. On the other hand, in the sample with CP, the number dropped in Excellent increased significantly ($p < 0.05$) in the white target, whereas that dropped in Normal decreased significantly ($P < 0.01$) in black target.

CONCLUSIONS: These findings suggest that visual clues would affect the performance and skills in daily living of individuals with CP.

PI.53 Neuromuscular coordination and recruitment differences of badminton forehand overhead smash executed by elite and non-elite athletics

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BACKGROUND AND AIM: The badminton forehand overhead smash (BFOS) is one of the high speed motions among various racket sports. Among overhead athletes the risk of shoulder injury may be increased with the style of stroke, the length of the throw, the level of athlete, and the level of associated muscle fatigue that happens during trainings. The recognition of muscle coordination and EMG patterns in elite and non-elite players can characterize the motor control patterns and neuromuscular coordination promoted with training [1]. Therefore, the aim of this study was to compare the muscle activation, onset/offset firing and duration time of BFOS between elite and non-elite groups in order to finding motor strategies differences between groups for the recognition of neuromuscular coordination.

METHODS: Twenty volunteers divided two group in the study, all elite players (12 persons) with mean practice of 15 years and amateur group (8 persons) without previous professional experience (Age of 23 ± 45 years, height of 173 ± 61 cm, weight of 67 ± 89 kg). The muscle activity of five muscles of the upper limb was recorded: the deltoid (DL), the infraspinatus (IS), the biceps brachii (BB), the supraspinatus (SS), the serratus anterior (SA). The EMG data acquisition was done with a sampling frequency of 1000 Hz. Raw EMG signals were digitally filtered (10-400 Hz) and the full wave was rectified and smoothed by with a low pass filter of 8 Hz (Butterworth, 4th order).

RESULTS: The mean values of MVC%, root mean square (RMS), standard deviation (SD), onset and offset time activity of each muscles and significant differences between the two groups are summarized in Table 1. Contact points in elite and non-elite groups are 70% and 61% of normalized time respectively. In the comparison of the average and peak value of elite and non-elite players the biceps, infraspinatus and deltoid demonstrated more than activity in elite groups. Significant differences between the two groups could be observed in the muscle activity, onset and offset time. Significant difference could be observed in the MVC% of the infraspinatus (Table 1). Table 1: Statistical information of EMG (MVC %) and onset-offset time in elite and non-elite groups for different muscles. Significant differences between groups could be observed in the activity of the deltoid. Soonest time of firing among muscle activities could be observed in the infraspinatus of elite and serratus anterior of non-elite group at 4%. Latest time of firing among muscle activities could be observed in the deltoid of elite at 65% and supraspinatus of non-elite group at 59%. Soonest time of offset firing among muscle activities could be observed in the deltoid of elite at 65% and supraspinatus of non-elite group at 59%. Latest time of offset firing among muscle activities could be observed in the infraspinatus of elite at 51% and deltoid and supraspinatus of non-elite group at 85%. During BFOS the serratus anterior was maximally active duration (84%) while supraspinatus were minimally active duration (26%) in the non-elite group. On the other hand, the biceps brachii demonstrated maximal duration activity (59%) and deltoid demonstrated minimal duration activity (19%) in the elite group.

CONCLUSIONS: Overhead movement is a complex motion that uses different muscles in different positions and firing time. The skilled players hits a ball accurately, quickly and repetitively because these muscles are well-coordinated and well-conditioned. Among the five muscle groups studied during the smash stroke, the EMG activity of infraspinatus was the greatest. The results showed that there were significant differences in peak and average, activation duration time and onset/offset firing time between the elite and non-elite. The surface EMG activity of elite group of BB, IS and DL muscles were stronger than that of non-elite group. The sequence of the movement and muscle recruitment timing and amplitude of elite and non-elite were different. The onset of EMG signal of IS and SA were significant differences between elite and non-elite groups. However, the offset of EMG signal of IS was significant differences between elite and non-elite groups. This suggests that different neuromuscular control and proprioception of non-elite cause different muscle coordination during throwing. The comparison of results of MVC% and firing time in the percent of the trial time may strengthen our belief that the different motion patterns could be characterized by MVC and by firing time in the percent of trial time. We recommend that the badminton players include exercises to strengthen the Infraspinatus in their training programs. This will result in increased power and ability when performing the BFOS in badminton competitions.

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		Average	RMS	Peak	Standard Deviation	Onset (Time %)	Offset (Time %)	Duration (Time %)
Supraspinatus	Elite	16.97	19.63	39.66	11.85	42	87	45
	Non-Elite	18.99	25.43	58.93	36.74	59	85	26
Biceps Brachii	Elite	4.97	5.35	8.80	7.93	37	96	59
	Non-Elite	2.22	2.66	5.40	3.29	46	89	43
Infraspinatus	Elite	49.65	55.49	80.83	29.91	4	51	47
	Non-Elite	29.02	34.89	62.24	62.23	41	90	49
Deltoid	Elite	8.96	10.26	23.59	8.15	65	84	19
	Non-Elite	2.46	3.44	7.95	6.27	42	85	43
Serratus Anterior	Elite	14.71	18.71	41.73	24.55	50	96	46
	Non-Elite	26.56	28.90	46.65	14.64	4	88	84

PI.54 Angular acceleration of the head of snowboarder that immobilizes the head

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Introduction: In general, concussion in sports players is diagnosed by a neurologic examination or diagnostic imaging. Although imaging by CT or MRI is effective for diagnosing severe head injury, most sports-associated concussions do not manifest as obvious damage inside the cranium. Thus, kinematic analyses of the head have been performed on simulations of contact sports, with angular acceleration regarded as an indicator of severe head injury. The frequency of head injury in snowboarder is high. The objective of this study was to measure the angular acceleration of the head occurring when a snowboarder falls and to determine methods that could effectively prevent head injury. Materials &
Methods: A woman snowboarder at the beginner level with a regular stance was selected. Various patterns of falls during freestyle snowboarding were filmed on a slope with an angle of 10 degrees. Two fall patterns were evaluated, a forward fall, in which a snowboarder fail to switch the edge of the board from the toe side to the heel side of the snowboard, causing the snowboarder to lean forward onto the lower side of the slope; and a backward fall, involving the inverse pattern. A wireless multifunctional sensor was attached to the center of the posterior surface of the head of the subject. To orient the static coordinate system, the point of sensor installation was set as the origin of the coordinate axes, the vertical direction was set as the x axis, the lateral direction as the y axis, and the longitudinal direction as the z axis. Snowboarding performance was filmed with a high speed camera. Using software equipped with video, a record of sensor data and review functions, and with a sampling frequency of 50 Hz. Obtained angular velocity was subsequently differentiated by time generating angular acceleration. Weighted investigation compared a control group with a group in which Philadelphia cervical collars immobilized the head.

RESULTS: The mean (SD) peak head angular acceleration on the y axis in backward fall was 422.0 (102.4) rad/s-2 in the control group and 388.8 (103.9) rad/s-2 in the group with immobilized heads. The Mann-Whitney-U-test (non-parametric data unpaired) confirmed this difference was statistically significant $z = -2.25$, $P = 0.025$.

Discussion & Conclusion The reverse-edge phenomenon in snowboarding can result in severe head injury. Because a typical backward fall increases the angular acceleration of the head in reverse-edge snowboarding, rotary movement of the head on the frontal-horizontal axis is thought to be harmful. This study found that immobilizing the head reduces angular acceleration on the frontal-horizontal axis during backward falls. Further research is required to analyze additional fall patterns in snowboarding and investigate the risk threshold of kinematic parameters of the head.

REHABILITATION/REHABILITATION TECHNOLOGIES

PI.55 Electromyographic analysis of shoulder girdle muscles in swimmers with shoulder pain

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Background and Aims: shoulder pain is a common complaint among elite swimmers. The purpose of this study was to determine activity of key shoulder girdle muscles in elite swimmers with shoulder pain compared to their counterparts without pain during a functional task.

METHODS: Nine swimmers with shoulder pain (mean age: 18.5±3.1 years, weight: 74.33±2.9 kg, height: 179±5.9 cm) and nine swimmers without shoulder pain (mean age: 18.1±1.6 years, weight: 73.33±6.6 kg, height: 178.3±5.07) were recruited. surface electromyography's (EMG) was recorded from the key shoulder girdle muscles unilaterally. the normalised root-mean-square value was used to assessed the muscular activation during the functional task done with pen marking on paper in counter clockwise direction.

RESULTS: The results showed significant differences between the muscles activity of Upper Trapezius(p=0.002), Serratus Anterior(p=0.023) and Latissimus Dorsi(p=0.002) between the groups.
CONCLUSION: swimmers with shoulder pain demonstrated greater activation of the Upper Trapezius, Serattus Anterior and Latissimus Dorsi muscles during the functional task while no activation was found in the activation of the Middle and Lower Trapezius, Middle Deltoid and Sternocleidomastoid muscles between the groups. Altered muscles activation in swimmers with shoulder pain has important implications for the development of evidence-base rehabilitation programs.

PI.56 A previous knee injury leads to an increase in intermuscular synchronization of the vastii muscles

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BACKGROUND AND AIM: The synchronization of motor unit activity between synergistic muscles represents a neuromuscular strategy to promote skilled muscle synergies during dynamic tasks. An intra-articular knee injury affects the function of the entire neuromuscular system and can lead to long-lasting adaptations in cortical and spinal excitation pathways both of which are involved in controlling intermuscular synchronization. A change in intermuscular synchronization between quadriceps muscles may alter the loading patterns experienced by the soft tissues within the knee joint and contribute to post-traumatic joint degeneration. Therefore, the aim of this study was to investigate the effect of a previous intra-articular knee injury 3-12 years ago on the degree of intermuscular synchronization as measured by the coherence between EMG signals of Vastus Lateralis (VL) and Medialis (VM) during gait.

METHODS: Participants were a subset of the Alberta Youth Prevention of Early Osteoarthritis (PrE-OA) cohort study. Specifically, this study included 30 young adults (59% female) who had sustained an intra-articular knee injury 3-12 years prior and 33 young adults (65% female) with no history of knee injury. VL and VM surface EMG signals were obtained from both legs during two minutes of treadmill walking (4.5 km/h). A coherence analysis was performed between the raw EMG signals of VL and VM for 40 steps per leg and subject. The mean of the coherence spectra for frequencies between 10-100 Hz were determined and compared between the injured and non-injured legs in previously injured participants and between the non-dominant and dominant legs in control participants using a paired t-test (α=0.05).

RESULTS: Five previously injured participants (3 females, 2 males) had also sustained a contralateral knee injury and were thus excluded from this analysis. The mean VL-VM coherence was significantly higher in the previously injured leg compared to the non-injured leg in individuals with a previous knee injury (Figure 1). In contrast, there was no significant difference in VL-VM coherence between the dominant and non-dominant legs in individuals with no injury history.

CONCLUSIONS:A history of knee injury was associated with an increase in the intermuscular coherence between the vastii muscles during gait. Intermuscular coherence has been shown to be related to the level of intermuscular motor unit synchronization originating from common cortical inputs to motor neurons that innervate synergistic muscles. Previous investigators reported an increase in cortical excitability as a potential strategy of the central nervous system to mediate deficits in joint afferent feedback following an ACL injury, which could explain the observed increase in intermuscular synchronization in this study. The effect of varying degrees of intermuscular synchronization between quadriceps muscles on knee joint mechanics is not well understood and should be the focus of future research.

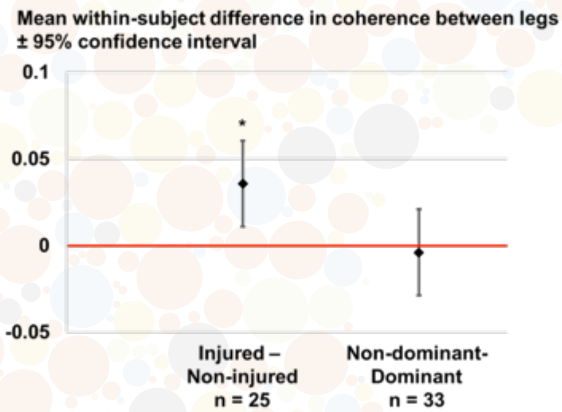

Figure 1: Mean difference in coherence (±95% confidence interval) between the injured and non-injured leg in previously injured individuals and non-dominant and dominant leg in control individuals. Asterisk marks a statistically significant paired t-test between legs.

PI.57 Maintaining lumbar spine stability: A study of the specific and combined effects of abdominal activation and lumbar belt on lumbar intrinsic stiffness

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BACKGROUND AND AIM: Low-back pain is one of the leading cause of disability worldwide. Inadequate lumbar stability is hypothesized as a potential injury mechanism. Two potential interventions for enhancing lumbar stability are increasing lumbar stiffness passively using a lumbar belt (LB) and actively increasing abdominal muscle activity. The aims of the present study were twofold: 1) to compare how two methods of activating abdominal muscles affects lumbar stiffness, and 2) to compare the effect of active muscle activation and the passive use of a lumbar belt (LB) on lumbar stiffness.

METHODS: Twenty-five healthy subjects completed seven experimental conditions, to assess the effect of different interventions on lumbar stiffness. Prior to these conditions, subjects were familiarized with the abdominal drawing in maneuver (ADIM), using ultrasound feedback, and with bracing of the entire abdominal wall using EMG feedback of the external oblique (EO). A surrogate measure of lumbar stability, lumbar stiffness (K), was computed as the dynamic relationship between perturbations of the trunk and torque produced in response. Each trial lasted 75 s while the trunk was perturbed continuously by 4-mm front/back disturbances. Subjects' lumbar stiffness were assessed under seven conditions: (C1) control; (C2) ADIM; (C3) 5% EO activation; (C4) 10% EO activation; (C5) elastic LB; (C6) LB + 5% EO activation; (C7) LB + 10% EO activation. For EO activation conditions, EMG biofeedback of the EO was provided concurrently on the monitor. For the ADIM, the experimenter ensured that the isolated contraction of the transverse abdominus was sustained, using ultrasound.

RESULTS: A 1-way ANOVA (C1, C2, C3, C4) showed that relative to control (2365, SD: 970 N/m), K significantly increased to the same extent during ADIM (2910, SD: 1337 N/m) and 10% EO activation (3361, SD: 1489 N/m). Bracing at 20% (EO activation) was significantly higher than at 5%. A mixed-effect model, where EO was a continuous factor, LB was a fixed factor, subject was a random factor, and K was the outcome variable, tested the effect of EO activation and LB on lumbar stiffness. There was a significant effect of EO activation on lumbar stiffness ($p < .001$), as K increased by approximately 100 N/m for every 1% increase in EO activation. There was also a significant effect of the LB on lumbar stiffness as using the LB increased K by 725 N/m ($p = 0.001$). The effect of EO activation and use of LB are independent as there was no interaction between the two factors ($p = .945$).

CONCLUSIONS: Bracing and ADIM produced comparable K values as they were performed at the same overall abdominal activation levels (5 to 10% MVC) [2]. The independent effect of bracing and LB raises the possibility of combining these interventions in some circumstances.

REFERENCES: [1] Lariviere et al. (2015). J Biomech, 48 : 254-261; [2] Vera-Garcia et al. (2007). J Electromyogr Kinesiol, 17: 556-567.

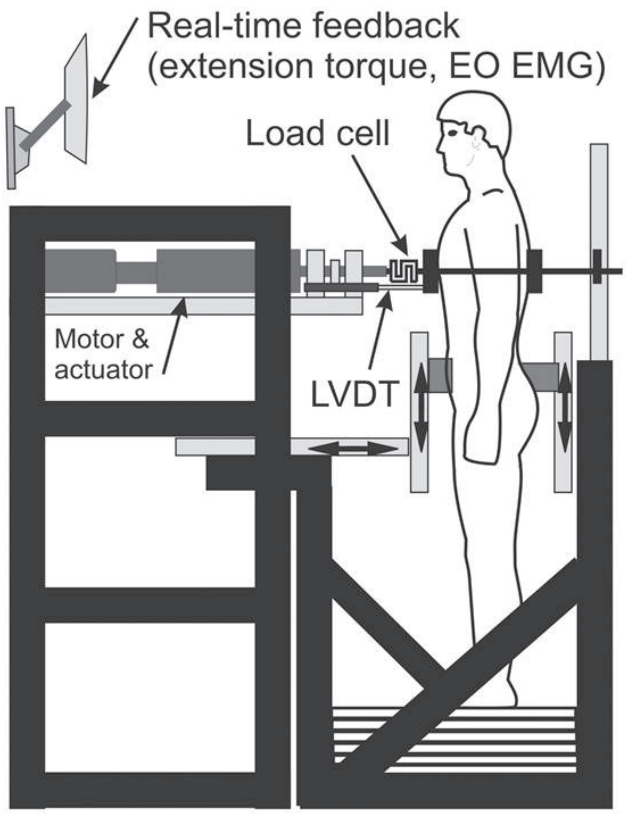


Figure. Trunk perturbation apparatus allowing to measure forces and movements applied on the trunk. (LVDT: Linear Variable Differential Transformer.

PI.58 The Effect Of Instruction On The Activity Of Ankle Muscles While Individuals Stand With The Emg Biofeedback

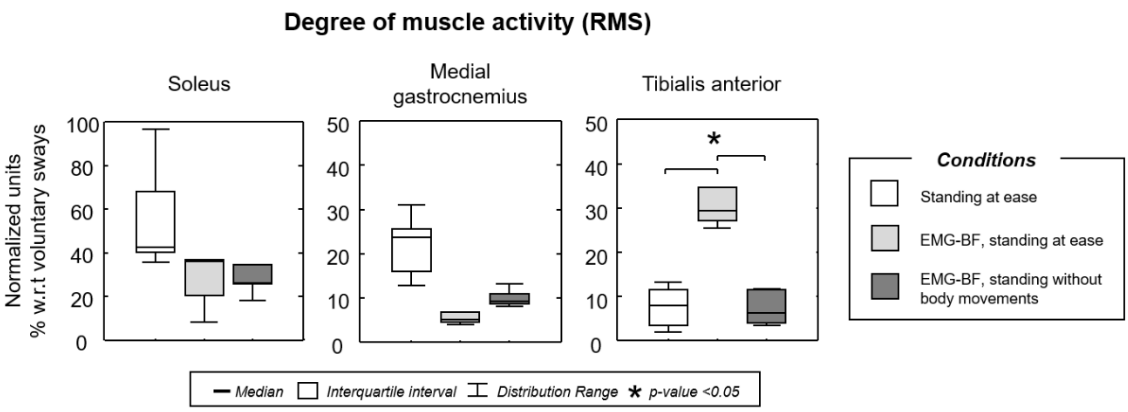
Fabio dos Anjos, Marco Gazzoni, Taian Vieira
Politecnico di Torino

BACKGROUND AND AIM: Biofeedback based on surface electromyograms (EMGs) has been proposed to suppress the excessive muscle activity during standing. However, the effect of EMG biofeedback driven by different verbal instructions on the ankle muscles' activity during standing is still an open question we address here.

METHODS: Five male volunteers were asked to stand barefoot comfortably with their arms alongside the body and eyes open. Three 60 s standing conditions were tested. Subjects were instructed to stand: 1) at ease without EMG-audio feedback from plantar flexors; 2) at ease with EMG-audio feedback; 3) without moving their head, trunk and upper and lower limbs with EMG-audio feedback. Surface EMGs from the soleus medial aspect, medial gastrocnemius and tibialis anterior of both legs were sampled with a pair of surface electrodes. The Root Mean Square (RMS) amplitude of EMGs over the whole standing duration was averaged across sides to assess the degree of postural activity for each muscle. The effect of instruction on the degree of muscle activity while subjects stood with the EMG-biofeedback was assessed with Friedman ANOVA by ranks, with standing conditions as repeated measures. Paired comparisons were made with Wilcoxon signed-rank test, considering the significance level of 5%.

RESULTS: The level of ankle muscles' activity varied with standing conditions (Friedman ANOVA main effect; $P<0.05$ for tibialis anterior). The EMGs' RMS amplitude sampled from soleus and medial gastrocnemius was lower (~15% in four out of five subjects) with than without EMG biofeedback, regardless of instruction (Friedman ANOVA, $P=0.09$ and $P=0.07$ respectively). Higher RMS amplitude, however, was observed for the tibialis anterior (~20%) while subjects stood naturally with the EMG biofeedback with respect to the other standing conditions ($P<0.04$ in both cases; Figure 1).

CONCLUSIONS: Results revealed the effect of EMG-biofeedback seems to depend on the instruction given to participants. When subjects performed the EMG-biofeedback condition while standing without moving the body segments, they could activate to a lesser extent their plantar flexors without increasing the level of dorsal flexors (Figure 1). Instruction seems therefore to enhance the effect of EMG-audio feedback during standing.



PI.59 Effects of Isometric Contractions Superimposed on Vibration Stimulation in Upper and Lower Limb Muscles for Rehabilitation Applications

Amit Pujari[1], Richard Neilson[2]
[1]University of Hertfordshire and University of Aberdeen, [2]University of Aberdeen

BACKGROUND AND AIM: Indirect vibration stimulation modalities such as Whole body vibration (WBV) and Upper Limb Vibration (ULV) are being increasingly used and researched as a tool for rehabilitation applications [1]. Many of the current WBV and ULV devices are mainly being investigated for increasing muscle strength and to positively affect bone modelling. However, there is a lack of evidence on the effectiveness of different vibration frequencies, amplitudes on neuromuscular performance to increase muscle strength; especially when the vibration stimulation is combined with voluntary isometric contractions of various levels. Also, methodology to establish effective vibration protocol suitable to an individual's requirement and capacity is currently unavailable. Muscle activation during vibration can be monitored and analysed with the electromyography (EMG) signal. As the EMG amplitude increases in parallel with the levels of force produced by muscles [2], the increase in EMGrms (root-mean-square) is representative of an increase in force level. Therefore, EMG signal could be used to measure and analyse the muscle activation during vibration exercise.

METHODS: We have designed and tested vibration devices, separately for the upper limb [3] and the lower limbs [6]. The novel designs of these devices, allow users to expend voluntary force while receiving vibration stimulations. Further, the use of appropriate actuators, piezoelectric actuator for the upper limb device and contra-rotating motors for the lower limb device ensures that appropriate range of vibration frequencies and amplitudes can be delivered reliably. Series of experiments were carried out on healthy volunteers (n=13), to test performances of the vibration devices and to test the effectiveness of vibration stimulation in increasing muscle strength. On the WBV device, variables tested were 30 and 50Hz frequencies, 0.5 and 1.5mm amplitudes at 20, 40, 60, 80, and 100 % of maximal voluntary contraction (MVC). On the ULV device, variables tested were 30Hz frequency at 80% of maximal voluntary fatiguing contractions.

RESULTS: For both the WBV and ULV devices, i.e. for the lower and upper limbs respectively, significant increases ($P < 0.05$) in the EMGrms activity of the principle muscles involved (agonist and antagonist) in the exercise were observed.

CONCLUSIONS: These results show that specific vibration frequencies (30Hz, 50Hz) and amplitudes (0.5mm, 1.5mm) when combined with graded isometric contraction(s) lead to increased neuromuscular response. These findings can be used to tailor specific exercise regimes to increase muscle strength for various rehabilitation applications and populations.

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PI.60 Cross-education does not accelerate the recovery of muscle strength and neuromuscular function after ACL reconstruction: a randomized controlled clinical trial

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BACKGROUND AND AIMS: Anterior cruciate ligament (ACL) surgery restores knee stability but impairments in quadriceps strength, neuromuscular control, and proprioception are present in both legs up to two years after surgery. These bilateral impairments are likely caused by aberrations in the sensorimotor system as an ACL injury disrupts sensory feedback and affects the motor output to the quadriceps. Bilateral improvements in motor output can be obtained by the cross-education of strength, which is the improvement in strength of the untrained side after resistance training of the contralateral side. Therefore, cross-education might improve quadriceps strength of the reconstructed and non-injured leg when added to the early phase of ACL rehabilitation. Our hypothesis was that cross-education, as an adjuvant to standard therapy after ACL reconstruction, would increase muscle strength and neuromuscular function.

METHODS: Patients with a unilateral ACL tear were randomized into an experimental (n=22) and control group (n=21). Both groups received standard rehabilitation after ACL reconstruction. In addition, the experimental group performed quadriceps strengthening exercises with the non-operated leg in weeks 1-12 after surgery (i.e., cross-education). The primary outcome was maximal isometric quadriceps torque and secondary outcomes were single- and multi-joint neuromuscular functions. All outcomes were measured in both legs 29 ±23 days prior to surgery and at 5, 12, and 26 weeks post-surgery.

RESULTS: For the primary outcome, the limb symmetry index of quadriceps torque was 9-10% worse for the experimental than control group at 5 and 12 weeks post-surgery ($p \leq 0.030$). Time effects revealed that maximal quadriceps torque in the reconstructed leg decreased 38% and 16% at respectively 5 and 12 weeks post-surgery and improved 6% at 26 weeks post-surgery (pooled across groups, all $p \leq 0.015$). The non-injured leg showed a gradual increase in maximal quadriceps torque up to 8% at 26 weeks post-surgery (pooled across groups, all $p \leq 0.001$). One secondary outcome showed a group by time interaction: voluntary quadriceps activation of the reconstructed leg was 6% reduced for the experimental vs. control group at 12 weeks post-surgery ($p=0.023$). Time effects for maximal isometric hamstring torque indicated 43% and 21% deficit respectively at 5 and 12 weeks post-surgery for the reconstructed leg and 7% improvement at 26 weeks post-surgery for the non-injured leg (pooled across groups, all $p<0.001$). At 26 weeks post-surgery, both legs improved force control (22-34%) and dynamic balance (6-7%) and the non-injured leg improved 2% in hop distance (pooled across groups, all $p \leq 0.043$). Knee joint proprioception and static balance remained unchanged.

CONCLUSION: Quadriceps peak torque and neuromuscular function were recovered at 26 weeks post-surgery, with no added benefits of cross-education training over the standard rehabilitation program.

PI.61 The effects of static stretching on range of motion and shear elastic modulus with different rest interval duration

Masatoshi Nakamura, Ryo Hirabayashi, Takanori Kikumoto, Emi Nakamura, Wataru Ito, Mutsuaki Edama
Niigata University of Health and Welfare

BACKGROUND AND AIM: Static stretching (SS) is commonly performed as a part of a warm-up routine to increase joint flexibility, improve performance, and reduce risk of injury. Previous studies have highlighted an immediate decrease in the shear elastic modulus after SS. In addition, the previous studies have reported that the effect of SS is affected by the duration and intensity of SS. However, the effects of rest interval duration during SS on the range of motion (ROM) and shear elastic modulus are unclear. AIM: This study aims to assess whether SS for a constant total time (300 s) with different rest interval durations produces different changes in ROM and shear elastic modulus.

METHODS: The subjects comprised 15 healthy young males. Each participant underwent three different rest interval durations during SS (i.e., Long duration: 90 s, Normal duration: 30 s, Short duration: 10 s). In addition, each experimental protocol was randomly conducted with at least a 3-day interval and no longer than a 10-day interval between testing sessions. SS of 300 s comprised 10 repetitions of SS maneuverer, which was held at the dorsiflexion ROM, i.e., the angle achieved by the participants without pain for 30 s. The shear elastic modulus of the medial gastrocnemius muscle was evaluated at 0˚of plantar flexion with the hip and knee joints fully extended using ultrasonic shear wave elastography. In addition, ROM was measured during passive dorsiflexion using a dynamometer. Shear elastic modulus and ROM were measured before and immediately after SS. We used the two-way repeated analysis of variance [3 experimental protocol (Long duration vs. Normal duration vs. Short duration) ′ test time (before and immediately after SS)] to analyze the interaction effects. A significant difference was determined between before and immediately after SS in each experimental protocol using a paired t-test. We considered differences to be statistically significant at an a level of $P < 0.05$.

RESULTS: The results of this study showed that there were no significant interaction effects on the shear elastic modulus and ROM. However, in all experimental protocols, while the shear elastic modulus immediately decreased after SS, ROM immediately increased after SS.

CONCLUSIONS: This study concludes that SS for a total of 300 s decreases the shear elastic modulus and increases ROM irrespective of the rest interval durations between SS.

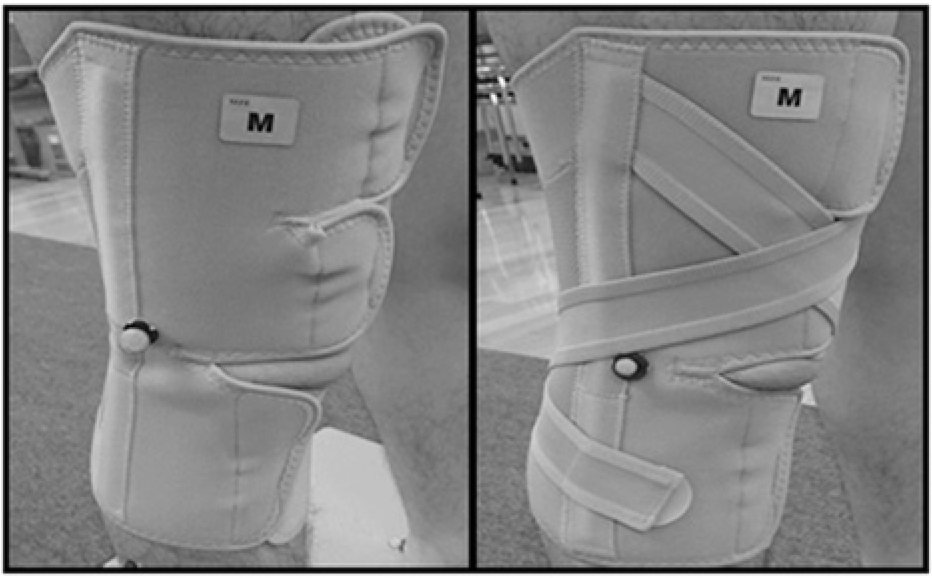
PI.62 Dynamic gait analysis with two types of knee orthosis in healthy adults

Keio Ishiguro, Takashi Nakayama
Tokyo University of Technlogy

INTRODUCTION We selected two different types of flexible knee orthosis, which are often used as a treatment method in conservative therapy of knee joint disease, and analyzed their effects with a three dimensional analyzer (VICON) and electromyography (NORXON) with the hope of gaining a better understanding of their effects on dynamic gait in healthy adults.

Methods: Seven healthy adult students participated in this study. Their mean (standard deviation) age, height, and weight were 21.0 years, 170.5 (6.8) cm, and 61.7 (8.3) kg, respectively. Before the experiment, the purpose and procedure of the study were explained in detail to all the subjects, and informed written consent was obtained. Dynamic gait without a knee supporter, with a knee supporter with side stays and with a knee supporter with side stays and a cross belt (Figure 1.) was investigated in this study. We synchronized the electromyography (Noraxon) with a three dimensional motion analyzer (VICON Nexus) to measure the joint angle of the right lower limb, joint moment, electromyography of 5 muscles (anterior tibialis, gastrocnemius lateral head, medial vastus lateralis, vastus medialis, and biceps femoris), and three floor reaction force components (left and right, front and rear, and vertical). Subjects walked four times at a comfortable speed without and with both types of knee orthosis. Data from the stance period of each of the four walking bouts were normalized to 100%, and multiple mean values were calculated. Statistical analyses were conducted using one-factor ANOVA and Tukey-Kramer tests. Before the measurements were taken, the subjects were allowed to practice walking without and with the two different types of orthosis in order to achieve a comfortable gait.

RESULTS AND CONCLUSION The vertical component average value of the floor reaction force was significantly larger in the knee supporter with side stays and cross belt ($p < 0.05$) compared to without a knee supporter. We found that as the centrifugal contraction of the quadriceps femoris was inhibited when wearing the knee supporter with side stays and cross belt, impact absorption was insufficient and the vertical component of the floor reaction force increased. Therefore, we believe that further investigation is necessary in order to establish the efficacy of the use of knee orthoses, especially those with side stays and cross belt, in the treatment of knee joint disease.



Knee supporter with side stays — Knee supporter with side stays and cross belt

Figure 1. Two types of knee orthosis investigated in this study.

PI.63 Participants' views on the blinding aspect of a RCT study - Experiences from evaluation of TES concept for self-administered treatment of spasticity

Leif Sandsjö[1], Jenny Alwin[2], Ann Sörbo[3], Marie Lindgren[4], Per Ertzgaard[2]
[1]University of Borås, [2]Linköping University, [3]Södra Älvsborg Hospital, [4]Linköping University Hospital

BACKGROUND AND AIM: Spasticity is a common consequence of injury to the central nervous system negatively affecting patients' everyday activities. Drug therapies, physiotherapy and electrotherapy are established treatments in spasticity but depend on the access to healthcare personnel. A treatment concept based on an assistive technology (AT) Mollii® (Inerventions, Stockholm, Sweden) with electrodes for multifocal transcutaneous electrical stimulation (TES) integrated in a full body garment makes self-administration of individualized electrotherapy possible. We have evaluated this concept in a randomized, controlled, double-blind, cross-over study in spasticity due to stroke or CP (Ertzgaard et al.; Epub ahead of print; DOI: 10.23736/S1973-9087.17.04791-8), showing general improvements in mobility, but without any statistically significant difference between the active (TES) and control (wearing the garment but with no TES) treatment periods. In order to not reveal any information about the active/non-active treatment, i.e. keeping the intervention blind to the participants, no communication was allowed between the therapist and the participant during the programming of the individualized TES concept at the start of the study. The AIM of the present study was to investigate the blinding aspect of the RCT based on the study participants' response in a follow-up questionnaire.

METHODS: The participants (n=27) used the AT with and without electrical stimulation (active/non-active period) for six weeks each. The RCT study protocol included a questionnaire item after the 2 six weeks periods asking whether the participants could tell which of the two periods that was the active period and, if so, Why do you believe that was the active treatment period?.

RESULTS: Nineteen participants (70%) could point out which period was active while three (11%) stated the wrong treatment period. Five (19%) responded I cannot tell which the active period was. The reasons given by the 19 who was right about the active treatment period included reports in line with the intended therapeutic effect of the stimulation (e.g. The second period because then the left hand was less spastic) from 6 participants. Five mentioned tingling sensations (likely caused by the electrical stimulation) while 8 participants mentioned both therapeutic effects and tingling (e.g. Felt like tingling and more flexible in the body) in their responses. DISCUSSION: Incidental findings from these questionnaire responses include that about half of the participants (14 out of 27) reported a therapeutic effect in line with the intervention. The intention to keep the RCT's intervention blind to the participants, e.g. not allowing communication about stimulation levels when programming the AT, may have resulted in that the TES were set too low to generate beneficial outcome related to spasticity in participants who could not tell which was the active period.

CONCLUSIONS: The results tell that the intention to keep the RCT-study fully blind to the participants did not work out as planned. As the compliance of the RCT was low (only fifteen of the participants adhered to the recommended use) the possibility to reveal the active/inactive period may have affected the compliance and the outcome of the study.

PI.64 Comparison between the EMG activation of supraspinatus and infraspinatus muscles during shoulder abduction movement while generating different hand grip strength in healthy subjects.

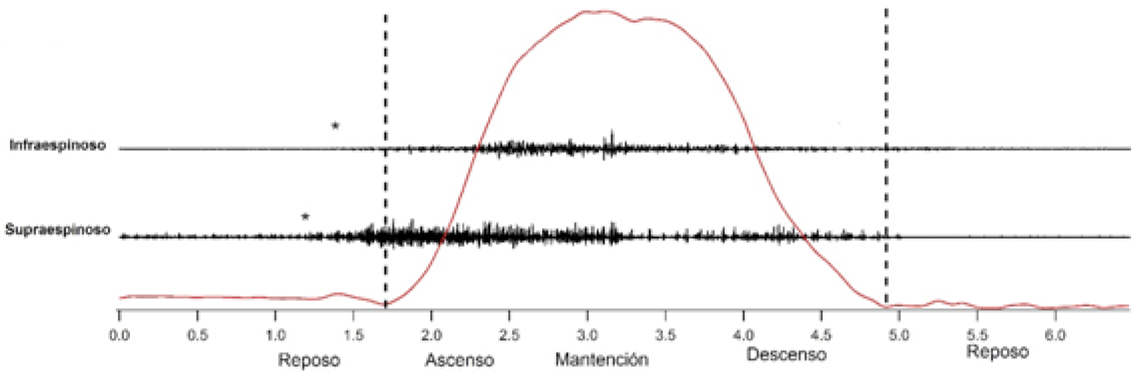
Macarena Soldan, Jorge Torres, Rony Silvestre
MEDS clinics

Background and aim: The glenohumeral joint has been described as a perfect balance between mobility and stability (Veeger, 2007). The supraspinatus (SS) and infraspinatus (IS) muscles have a stabilizing function during shoulder abduction. The objective of the present study was to compare de beginning of the electromyographic activation of SS and IS in the abduction movement while generating different hand grip strength (0%, 30% and 60% of the maximum voluntary contraction, MVC)

METHODS: The sample was made up by 20 healthy subjects, 13 men and 7 women. These subjects were gathered through a non-probabilistic sampling for convenience meeting with the inclusion and exclusion criteria. All subjects provided informed consent before participation and the procedures were approved by the Los Andes University Ethics Committee. For the EMG recording, a single differential EMG sensor (Trigno Lab System, Delsys Company) was used on the IE muscle. To record the SS muscle a Fine Wire technique was used(Chalgren Enterprises, Inc., Gilroy, California) with a 25ga. 50mm electrode. To define muscle activity onset three standard deviations from the signal base line vRMS were calculated. The subject did three shoulder abduction movements at three different levels of hand grip strength (0%, 30% and 60%). To measure the start of the abduction movement an accelerometer (Trigno Lab System, Delsys Company) was placed on the dorsal aspect of the wrist and acceleration on all axes was recorded. Hand grip strength was measured with a load cell (TSA Alloy Steel S, Type load cell, 3000N).

RESULTS: The results show that the SS and IF are active before the abduction movements starts at every level of hand grip strength studied. (Supraspinatus: - 0.59 +/- 0.12 to 0% MVC; - 0.58 +/- 0.10 to 30% MVC; - 0.52 +/- 0.09 to 60% MVC and Infraspinatus: -0.22 +/- 0.19 to 0% MVC; -0.06 +/- 0.18 to 30% MVC; -0.13 +/- 0.20 to 60% MVC).

CONCLUSIONs: When comparing the results there were no significant differences at the beginning of muscle activation for the SS although the IS is active earlier with a hand grip strength of 30% than without pressure. We can conclude that the SS and IE have an anticipatory muscle activation during an abduction movement and that the IS is a hand grip dependent muscle, meaning that it responds to a low load (30%MVC) with a more anticipatory response during a shoulder abduction movement.



POSTER PRESENTATIONS

Sunday, 1st July

2 Poster Session II, Sunday July 1st

BIOMECHANICS

PII.1 The effect of distal transverse arch on wrist joint during dart-throwing motion

Akio Ueda, Hiroshi Kurumadani, Shingo Matsumura, Toru Sunagawa
Hiroshima University

BACKGROUND AND AIM: The dart-throwing motion can be defined as the motion pattern which wrist functional oblique motion occurs specifically from radial extension to ulnar flexion. The dart-throwing motion utilizes the midcarpal joint to a great extent. It is used as the range of the motion exercise to expedite functional recovery for a patient who has a distal radial fracture. On the other hands , it is considered that the flattening of the distal transverse arch due to casting affects the mobility of midcarpal joint, but it has not been clarified that the relationship between the dart-throwing motion and flattening of the distal transverse arch. The purpose of this study is to clarify the influence on the motion pattern in the wrist during the dart-throwing motion with the flattening of the distal transverse arch.

METHODS: Twenty-two right-handed volunteers participated in this study. We measured the dart-throwing motion task under two conditions; with orthosis for the flattening of the distal transverse arch and without one. The task was repeated 10 times. The orthosis fixes the second to fifth metacarpal heads. A twelve-camera motion analysis system (VENUS 3D, Nobby Tech) recorded three-dimensional hand displacements with a sampling rate of 100 Hz. We calculated the angles of the wrist joint during tasks. Mean angles were produced by averaging across the 10 trials. The maximum angles from the mean angles of the tasks determined each angle of the flexion, extension, radial and ulnar deviation. In addition, we calculated the direction of motion as the motion pattern from radial extension to ulnar flexion. We used compared T-test to confirm the influence on the maximum each angle and the direction of motion between two conditions.

RESULTS: The maximum extension and ulnar deviation angle during the dart-throwing motion with orthosis were significantly decreased, but there was no significant difference between the two conditions of the other angles. And, there was a significant difference between the two conditions in the directions of motion during tasks.

Discussion: Flattening of the distal transverse arch restricted rolling of the midcarpal joint during the dart-throwing motion and limited the wrist joint angle. It is suggested that maintaining the distal transverse arch is important for acquiring the ranges of the motion during the dart-throwing motion.

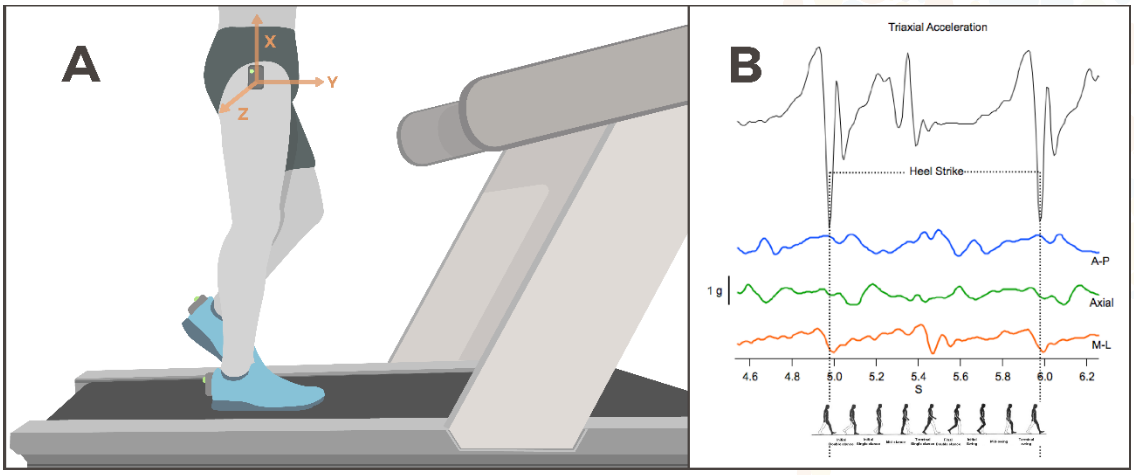
PII.2 Evaluation of Atraumatic Hip Instability Measured by Triaxial Accelerometry During Walking.

Iver Cristi-Sanchéz[1], Alejandro Neira[1], Tomás Amenabar[2], Claudio Rafols[2], Marcos Bellemi[2], Mariano Neira[2], Macarena Soldan[2], Rony Silvestre[2]
[1]Universidad Mayor, [2]Clínica MEDS

Background: Hip stability is accomplished by the interaction between the inherent bony congruence, the capsuloligamentous complex and the hip musculature. The combination of these structures enables the hip to be most the stable joint. However, changes in joint stability associated with injury leads to pain and joint degeneration. Hip joint instability is a major issue than results in higher intraarticular femoracetabular translations. These higher translations may be possible to be evaluated by human analysis movements methods. One of them are accelerometers that allows to measure segmental acceleration and evaluating human movement, especially during gait Aim To describe the triaxial and overall accelerations in patients diagnosed with atraumatic hip instability during gait cycle and compared those results with a control group.

Methods: Ten hip instability subjects and 10 healthy controls were evaluated in this study. A triaxial accelerometer (Trigno Wireless System, Delsys Inc, Boston, USA) was used to record acceleration during walking on a treadmill (x-axis: axial direction, y-axis: anteroposterior direction, and z-axis: mediolateral direction). The accelerometers were attached bilaterally to the skin with adhesive tape over the greater trochanter (Figure 1A). To identify the different gait cycles, two accelerometers were attached over each calcaneal tuberosity (Figure 1B) The overall magnitude of the acceleration was calculated to evaluate hip instability, obtained by the following equation: |a|=√(ax^2+ay^2+az^2). The mean magnitude of each direction (axial, anteroposterior and mediolateral axes) and the mean overall acceleration were compared with the control group.

Results: The mean overall acceleration was 1.51 ± 0.23 and 1.07 ± 0.16 g for the hip instability group and the control group, respectively. A significant difference was found between groups (p = 0.0001). Statistical analysis showed significant differences in the 3 axes for the comparison between groups. Conclusions Hip instability subjects had higher mean overall acceleration during walking compared to controls. The axial and mediolateral accelerations showed to be higher for the hip instability group while the anteroposterior axis acceleration was lower in the same group. These changes in accelerations may be explained as redistribution of hip intraarticular.



PII.3 Degradation study of biodegradable polylactic acid/ bioactive glass composite screw

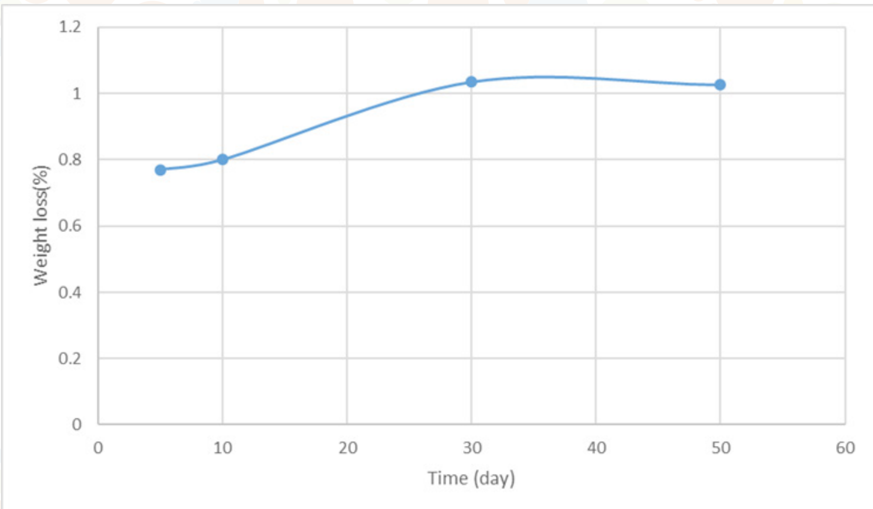
Amir Shafaat[1 2], Emad Hosseini[3], Anousheh Zargar Kharazi[3]
[1]Arak University of Technology 2.Isfahan University of Medical Sciences 3.Musculoskeletal Research Center Isfahan University of Medical Sciences, Isfahan, Iran, [2]1.Arak University of Technology 2.Isfahan University of Medical Sciences 3.Musculoskeletal Research , [3]Isfahan University of Medical Sciences

BACKGROUND AND AIM: Metal screws were used for fractures fixation and stabilize bone transplant. Despite establishing appropriate fixation, the metal screw had disadvantages such as high Young's modulus (100-200 GPa) and releasing harmful metal ions which means a second surgery needed to removed metal screws after the bone has healed. By using biodegradable screws, the problem of screw removal via a second surgery was solved.

METHODS: In this study, we manufactured a biodegradable polylactic acid (PLLA)/ bioactive glass (BG) composite screw with forging process in order to use in load-bearing orthopedic applications. For optimizing mechanical properties of composite screw used finite element method. Degradation test was performed in weight loss according to (ASTM F1634) standard. For degradation experiments, composite screws were immersing in a Phosphate-buffered saline (PBS) solution for seven weeks.

RESULTS: Results were showed a weight loss of all composite screws increased progressively with time during the soaking period. In the first week, weight loss was noticeable which presented in Fig. 1. In the composite screws, degradation process happens in the bulk of polymer also at the interface of matrix/reinforcement. In the polymer bulk, water molecules attacking to chemical bonds and break the polymer long chains into shorter parts. After shortening the chains, the composite mass is removed, and the loss is noticeable.

CONCLUSIONS: In polymeric matrix (PLLA), some parameters have an important role in degradation rates, such as molecular weight and polymer crystallinity that could reduce degradation rate depending on the fabrication process. In the second stage of degradation, the polymer/fibers interface would be degrading and debonding would be occurred. Therefore, more decreasing in strength would be observed. This composite screw shows close mechanical properties to cortical bone, which made it appropriate for load-bearing orthopedic applications.



PII.4 Use of principal component analysis to determine movement characteristics between countermovement jump with and without arm swing

Emily Cushion, Jamie North, Daniel Cleather
St Mary's University

Use of principal component analysis to determine movement characteristics between countermovement jump with and without arm swing Cushion, E., North, J. S., & Cleather, D.J. BACKGROUND AND AIM: It has been widely accepted that movement is inherently variable. Vertical jumping is a discrete skill requiring effective coordination of the lower and upper limbs for optimal movement, within which variations in movement strategies have been observed (Vanezis and Lees, 2005). Principal component analysis (PCA) is a technique that reduces multidimensional data to key features of a movement and highlight variations in the structure of a movement between individuals (Daffertshofer et al., 2004). This analysis can be valuable within biomechanical research to understand the structure of movements. In particular, it is interesting to compare similar movements, to better understand how added constraints may impact key movement features. Therefore, the aim of this study is to use principal component analysis to characterise the structure of the countermovement jump with and without the use of an arm swing.

METHODS: Thirty eight physically trained males (n=24) and females (n=14) took part in this research. Prior to commencing testing participants completed a warm up. Following this 18 reflective markers were placed on the right lower limb. Participants then completed five maximal effort countermovement jumps with hands on the hips. Following a two-minute rest participants then completed five maximal effort countermovement jumps with arm swing. A motion capture system (Vicon V5, Oxford, UK) was used to obtain kinematic data (500Hz) while two force plates (Kistler 9287BA, Kistler Instruments Ltd, UK) recorded ground reaction forces (1000Hz). Data was processed using freely available software (Freebody) and a standard inverse dynamics analysis was performed to obtain internal kinetic data. Each participant's data was normalised to allow comparison between repetitions. A PCA was performed on lower limb joint moment data for five repetitions of each style of jump.

RESULTS: The PCA highlights, from a representative individual skilled in jumping, that one principal component can explain over 90% of the variance in both styles of jumping (Table 1).

CONCLUSIONS: Initial results suggest the first principal component can be used to explain the majority of explained variance in the vertical jumping of a representative subject (both with and without arm swing). This poster will present a comparison of PCA results between individuals to establish if this finding is consistent among individuals from various training backgrounds.

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Table 1. Proportion of variance explained by principal components from CMJnas and CMJas from a representative participant.

PC	CMJnas	CMJas
1	91.752	92.080
2	6.322	6.829
3	1.270	0.644

PC = principal component, CMJnas = countermovement jump no arm swing, CMJas = countermovement jump with arm swing

PII.5 Deltoid antagonistic co-activation at different arm elevation planes

Vassilios Vardaxis, Jeff Mann, Jordan Estes, David Stapleton, Traci Bush
Des Moines University

BACKGROUND AND AIM: While the role of the anterior (AD) and posterior (PD) deltoid muscles in arm elevation is questionable, their respective contribution to flexion and extension of the glenohumeral joint (GHJ) is well supported. Data related to AD and PD function with respect to horizontal ad-/abduction and medial/lateral rotation are also conflicting. Modulation of the antagonistic AD-PD function can facilitate the arm elevation task at different planes, while providing humeral stability and potential alignment at the GHJ. This study aimed to quantify the relative co-activation of the AD and PD during arm elevation in different planes (between frontal and sagittal), indirectly assessing the alignment of the humerus to the scapular plane.

METHODS: Ten healthy, right-handed male subjects (mean age 24.5±1.34 years) were analyzed for the study. The mean BMI was 26.7 kg/m² (range 20.4 to 30.9 kg/m²). All subjects were tested on their dominant shoulder. Subjects elevated their arm (elbow extended) 4 times to approximately 120° (while seated) on each of 13 randomly ordered elevation planes (0,10,20,25,30,35,40,45,50,60,70,80, and 90° to frontal). Motion capture (10-camera Motion Analysis Corp) tracked arm elevation (120Hz). Surface electromyography (EMG) data was recorded (1200Hz) using an MA-300 system (Motion Lab Systems, Inc). Manual muscle testing (MMT) reference and dynamic EMG activation data was RMS processed and normalized to %MMT. Two-way repeated measures ANOVA was used to examine the plane of elevation effect on the muscle activation level at $\alpha=0.05$. A Directed Co-Contraction Ratio (DCCR) algorithm was used on EMG re-normalized to peak dynamic activation to evaluate the antagonistic co-activation of the AD and PD muscles.

RESULTS: Both muscles' activity increased significantly with the arm elevation angle, regardless of elevation plane. There was a significant muscle by elevation plane interaction effect (F=11.7, p=0.000), showing the AD activation level increasing as the elevation plane approached sagittal, opposite to PD that showed greater activation approaching frontal. There was also a significant muscle main effect (F=24.0, p=0.000), showing higher peak activation for the AD across all elevation planes (mean difference 30.0±19.8 %MMT). The DCCR shows a shift in the relative dominance in activation between the AD and PD at an elevation plane of 25.4° (SE=4.1°) to frontal (CI-95 = 16.2° - 34.5°). The elevation plane of AD to PD activation dominance change can be interpreted as a bias in the alignment of the humerus to the glenoid cavity reflecting the "scapular plane".

CONCLUSIONS: Both muscles contribute in the arm elevation task against gravity. The AD shows significantly higher activation, irrespective of the elevation plane. The muscle co-activation patterns are modulated with respect to the elevation plane toward the sagittal or the frontal plane for the AD and PD, respectively, shifting dominance at the scapular plane.

PII.6 A study of the toes pressing force in gait. : Analysis of the time when the pressing force peaked.

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Background and aim: No studies have analyzed how each toe is pressing to the direction of 3-axes in gait. If we can measure when and how strongly each toe is pressing the floor in gait, we can be used to judge the therapeutic effect in the hallux valgus. So far, we have been measuring the peak value of the floor pressing force (FPF) with toes in gait. Therefore, the purpose of this study was to show the feature of the time when the pressing force peaked in gait, by analyzing the FPF vector with great toe, 3rd toe, 5th toe, 1st metatarsal head, and 5th metatarsal head.

METHOD: This study was approved by the Ethics Committee of the Osaka Electro-Communication University. Eight college students without history of orthopedic disease participated. The walkway was a flat straight line of about 8 m, and participants walked as usual. We measured the FPF vector of right toes (great toe, 3rd toe, 5th toe) and 1st metatarsal head, 5th metatarsal head, heel. We used 3-axis force sensor (Tec Gihan Co. Ltd., Japan) for measuring anteroposterior (AP) component, lateral-medial (LM) component, and vertical (V) component of the FPF vector with each toe. We specified a walking cycle from the right heel contact to the right heel off. We analyzed the measured value of the FPF vector of each toe during a walking cycle. The number of measurements was three for each subject. We set the sampling frequency of small 3-axis force sensors to 100 Hz. In order to use the FPF vector taken in the comparison between participations, we normalized the time taken for a walking cycle. We took as the features value the times when the absolute value peaked while the right toe was in floor contact during one gait cycle. Hereafter, we expressed the features value as the time of AP component peaked, LM component peaked, and V component peaked.

Result: The time of AP and LM component peaked with great toe, were mainly distributed at each about 40 to 50% and about 50 to 60%. The time of LM component peaked with 3rd toe, 1st metatarsal head, and 5th metatarsal head, were distributed at about 50 to 60%. The time of AP component peaked with 1st metatarsal head and 5th metatarsal head, were almost distributed around 50%. The time of V component peaked with great toe, 3rd toe, 5th toe, 1st metatarsal head, and 5th metatarsal head, were almost distributed at about 45 to 60%.

CONCLUSION: In this study, we analyzed the FPF vector of each toe in gait, it was possible to clarify the features of the time when the FPF vector peaked in healthy subjects.

PII.7 Analysis of the 3-direction force for pedal and the muscle activity, the joint movement during the constant work rate pedaling.

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BACKGROUND AND AIM: There is diversity in the combination of the loading and the pedaling rate when the constant work rate pedaling. So that combination pattern is infinity. As a result, it changes the crank torque, the muscle activity, and the energy consumption, etc. The report of the pedaling rate with best energy efficiency is admitted at the constant work rate pedaling. However the report of the 3-direction Force for pedal that condition is few though. The purpose of this study was that the influence given to the characteristic of the 3-direction Force for pedal, the muscle activity and the joint movement when the pedaling rate was changed during constant work rate pedaling.

METHODS: Ten subjects participated in the study. This study was approved by the Ethics Committee of the Nara city hospital. Ergometric cycling was performed under five pedaling rates (30, 50, and 70,90,110) into work rates (150W). We used the dynamic sensor built-in crank. We measured it every crank angle of 15 ° that the force in the rotational direction of the pedal(Fè) and the force in the rotational axis direction of the crank from the pedal(Fr), the force in the direction in which the pedal shaft pushes the crank(Fz). We calculated the average 3-directon force for pedal during 15 revolutions for each pedaling rate. We measured crank angle and hip, knee and ankle angle on pedaling by 3D motion Analysis system. We used an active electrode, and the electromyography activity during ergometric cycling was measured in the vastus lateralis, semimembranosus, gastrocnemius lateralis, and tibialis anterior, all bilateral. We calculated Averaged Rectified Value (ARV) and normalized with the maximum isometric contraction of each muscle taken as 100%, and expressed as% ARV. For statistical analysis, we used repeated measures One-way ANOVA and Fisher 's PLD.

RESULTS: The force in the rotational direction of the pedal (Fè) decreased as pedaling rate increased. The force in the rotational axis direction of the crank from the pedal(Fr) in the radial direction decreased as pedaling rate increased. The force in the direction in which the pedal shaft pushes the crank(Fz) shifted from the inside to the outside as pedaling rate increased. As a result of comparing each 3-direction average force for pedal every crank angle of 15 °, the rotational direction of the pedal (Fè) was generated at an average of 102 °and the force in the rotational axis direction of the crank from the pedal(Fr) was a maximum value of 144 °.

CONCLUSIONS: It was thought that the force in the rotational direction of the pedal is generated at the crank angle of 90 °to 100 °at the slow pedaling rate and the force of the pedal to the rotation axis direction of the crank is generated at around 150 °at the high pedaling rate. These showed that the operation strategy of depressing the pedal is changed and the rotation is performed efficiently as pedaling rate increases.

PII.8 Walking critical speed percentage: oxygen consumption, step frequency and perceived effort

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BACKGROUND AND AIM: walking is one of the most popular activities for improve health and physical conditioning and has been practice for people who are physically active and sedentary, because presents low cost and minimal risk of injury. In healthy subjects, the optimal velocity is the self-selected speed. Studies on the physiological adaptations of self-selected walking practice present wide variability and controversial results. Some articles say that the self-paced walk is inadequate for maintenance of physical fitness because it is outside the training zone. Other findings report that the self-selected walking rhythm is sufficient to generate physiological changes. For correct prescription of aerobic exercises, it is necessary to check and control some variables such as heart rate (HR), oxygen consumption (VO2) and Rating of Perceived Exertion (RPE). Furthermore, the control of critical speed (CS) is interesting because it is a non-invasive and low-cost technique and can be easily applied without the need of equipment. This is the highest velocity that can be sustained for a long period without achieving maximum oxygen consumption. The aim of this study was to investigate the effect of the percentages of CS determined as Walking Speed (WS) on VO2, RPE and the SF during an incremental walking test.

METHODS: eight male subjects performed maximal repetitions with durations of six and nine minutes for the determination of CS. Subsequently, the subjects performed incremental exercise test in percentage of CS: five-speed six-minute duration each, the percentage of 75, 80, 85, 90 and 100% of CS.

RESULTS: the values of RPE increased with increasing the percentage of CS, showed by the results of WS (km÷h) and RPE which presented significant differences in the percentages of 75% (WS=6.48±0.25; RPE=10.50±1.29), 80% (WS=6.95±0.26; RPE=11.95±1.03), 85% (WS=7.42±0.26; RPE=13.10±1.24), 90% (WS=7,89±0,26; RPE=14,59±1,20) and 100% (WS = 8,80±0,26; RPE = 17,32±1,37) of Critical Speed ($p<0.05$). The SF and VO2 variables were not significantly different between the percentages of 75% and 80%, however the values of 85% (SF=70.22±3.04; VO2=23.81±4.82) and 90% (SF=73.67±4.91; VO2=26.92±4.50) of the CS ($p<0.05$) showed significant differences.

CONCLUSIONS: the percentage of CS determined in the respective speeds up the pace on self-selected walking can be used in an effective way to control the training.

PII.9 The influence of early radiographic evidence of knee osteoarthritis on muscle activation patterns and joint biomechanics: A between-limb comparison in people with unilateral symptoms

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Background and Aim: Muscle activation and joint mechanics during walking have been used to understand knee osteoarthritis (OA) joint function. While studies have greatly focused on the symptomatic knee, many people will experience OA in both knees during their lifetime. The purpose was to examine whether knee muscle activation patterns and biomechanics differ during gait between symptomatic and contralateral knees in people with early radiographic evidence of disease of equal severity compared to people with greater severity in the symptomatic knee.

METHODS: 62 people with unilateral symptomatic medial knee OA were recruited. Bilateral standing AP radiographs were evaluated using the Kellgren Lawrence grading system by an experienced clinician, blinded to gait outcomes and knowledge of symptomatic leg. Using standardized procedures, skin surface electrodes (Ag/AgCl) were placed in a bipolar configuration over the lateral and medial hamstrings, gastrocnemius and quadriceps. Retro-reflective markers were placed on lower limbs. Participants walked barefoot for at least five minutes on an instrumented treadmill at over-ground walking speed while ground reaction forces and electromyograms (EMG) were recorded at 2000Hz. Marker motion was captured a 100Hz. A 20-second recording was made at minute six. EMG were band-pass filtered (10-500Hz), corrected for subject bias, full wave rectified, low-pass filtered (6Hz) and amplitude normalized to maximal voluntary isometric contractions. Sagittal plane joint angles were calculated. Inverse dynamics was used to calculate sagittal and frontal plane knee moments. 20/62 individuals had an equal KL grade between symptomatic and contra lateral knees (equal). 13/62 had greater KL grade in the symptomatic knee (unequal). Analyses were completed on this subset. Discrete measures (i.e. peak KAM) were extracted from biomechanical variables. Principal Component Analysis was used to evaluate EMG waveform patterns. Analysis of Variance models (alpha=0.05) were used for statistical hypothesis testing.

RESULTS: Motion during stance and the difference between peak knee flexion and extension moments was less in the symptomatic knee compared to contralateral in the unequal group ($p<0.017$). No differences existed in the equal group or between contralateral knees. Overall hamstring activation (PP1-scores) was greater in symptomatic knee regardless of group ($p=0.006$). Both limbs in the equal group and the symptomatic limb in the unequal group presented with an earlier increase in gastrocnemius activation during mid to late stance (PP2-scores) ($p<0.05$). No differences were found in quadriceps or frontal plane moment characteristics.

CONCLUSIONs: An interaction occurs between symptoms and radiographic disease in explaining knee biomechanics and muscle activation in individuals with early knee OA. Knee symptoms and radiographic severity should not be used independently to explain knee function in early OA.

PII.10 Evaluation of shoulder stability in young and elderly subjects with helical axis technique

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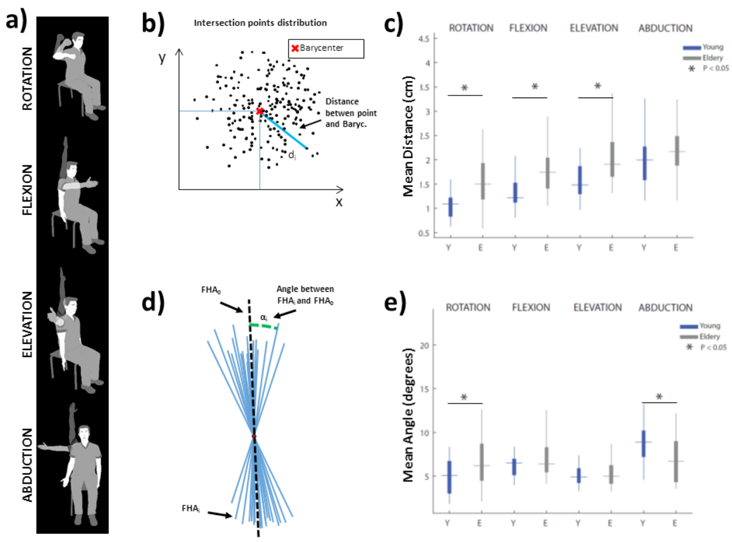
BACKGROUND AND AIM. The shoulder complex is composed of glenohumeral, scapulothoracic, acromioclavicular and sternoclavicular joints, it permits the arm and hand orientation and it has the highest degree of mobility in the human body. The location of the instantaneous axis of rotation of a joint can be estimated through the analysis of the Helical Axes (HA). The dispersion and orientation of HA can be used as an index of joint stability, and it has been applied to ankle, knee and cervical spine and their behaviour seems to depend on the features of joint surfaces. Several studies reported age-related changes in shoulder complex morphology due to the physiological joint surfaces degeneration in asymptomatic subjects, mainly due to the irregularities arising for the articular cartilage consumption. Therefore, the aim of this study is to observe differences in the HA dispersion in different age groups during different upper limbs movements.

Methods: Forty volunteers were enrolled in the study: 20 young (age 20-30 years) and 20 elderly (age over 65 years). Subjects were asked to perform four different movements with both arms, while being seated on a chair without back support. The movement types were: 1) ROTATION - shoulder internal rotation with their arm abducted 90 degrees laterally and elbow flexed 90 degrees. 2) FLEXION - complete shoulder flexion until 180 degrees along the sagittal plane. 3) ELEVATION - complete arm elevation until 180 degrees along an imaginary plane placed 45 degrees between the sagittal and the frontal plane.4) ABDUCTION - complete arm abduction until 180 degrees laterally within the frontal plane (a).Upper arm active movements were detected with an optical motion capture system (BTS SMART DX, Italy) consisting of six infrared cameras. Retro-reflective markers were placed on the trunk and on each of the two arms. The trunk was defined by four markers placed on the skin at the level of incisura jugularis, xiphoid process, seventh cervical vertebra and eighth thoracic vertebra. The arm was defined by a cluster of five markers on a plastic support fixed to the arm with Velcro straps. Intersection points of HA were identified by a set of equal spaced planes and the minimum average distance (MD) of the points from their barycentre was computed. In addition, the mean angle (MA) of the HA was computed (b,d).

RESULTS. A significant difference was observed between MD in the two groups during Rotation, Flexion and Elevation ($p<0.001$), with larger values for the elderly group (Figure c). MA was significantly higher for elderly subjects during Rotation ($p<0.001$), while it was lower during Abduction ($p<0.01$). (c,e)

CONCLUSIONS. The extraction of Helical Axes parameters showed to be a promising technique to analyse shoulder stability, allowing to observe differences between young and elderly subjects during controlled repetitive tasks.


a)
ROTATION
FLEXION
ELEVATION
ABDUCTION
b)
Intersection points distribution
Barycenter
Distance betwen point and Baryc.
y
x
c)
ROTATION
FLEXION
ELEVATION
ABDUCTION
Young
Eldery
P < 0.05
Mean Distance (cm)
d)
Angle between FHAi and FHA0
e)
ROTATION
FLEXION
ELEVATION
ABDUCTION
Mean Angle (degrees)

PII.11 Observing sEMG output when doing a maximum voluntary isometric contraction in supine position as compared to a maximum isometric contraction in standing position.

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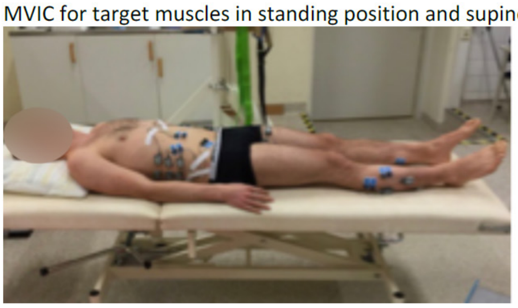
BACKGROUND AND AIM: When comparing muscle activity output between different individuals or between different conditions by using surface electromyography (sEMG) it is necessary to apply a standardized process. There is no golden standard as to which type of muscle performance used to retain reference EMG, but the most frequently used method is the maximum voluntary isometric contraction (MVIC) of the muscle in question. The supine or prone position is commonly used while achieving the MVIC of target muscles. It is postulated that the erect posture put a different demand on the muscles of the lower extremities and trunk as compare to the supine posture. This is due to the balancing effort the segmental chain alignment has to perform against the force of gravity in standing as compared to supine position. The aim of this study was to evaluate the normalizing method MVIC used in sEMG in supine position as compared to standing position for elected muscles of the lower extremity and trunk.

METHODS: Twelve healthy individuals volunteered to participate in the study; five female and eight male between the age of 22 and 51. Data were recorded bilaterally from six target muscles: mm tibialis anterior, gluteus medius, adductor longus, rectus abdominus, external oblique and internal oblique/transversus abdominus according to a given test protocol. Two different muscle test positions were used: supine position with trunk in neutral position, zero degree range of motion (ROM) in hip and knee, 90 degree dorsiflexion in ankle and standing position with equivalent ROM degrees as in supine.

RESULTS: Preliminary results show that there is no statistical difference in EMG output from target muscles for the two tested positions while performing a maximum isometric contraction.

CONCLUSIONS: Based on the preliminary result it seems indifferent which position preferred when performing MVIC of target muscles in the design of this study.

MVIC for target muscles in standing position and supine position



MODELLING, SIGNAL PROCESSING & SENSING

PII.12 Model of phase locking in the subthalamo-pallidal loop in Parkinson's Disease

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In Parkinson's disease, there is evidence that subthalamic nucleus (STN) and globus pallidus pars externa (GPe) neurons develop synchronized bursting activity as a result of pathological phase-locking to rhythmic cortical inputs. The mechanisms underlying this pathological bursting are not yet fully understood. Measures of bursting have been found to be correlated with severity of the symptoms bradykinesia and rigidity in both patients and in primate models of Parkinson's disease [1,2]. Though it is not clear whether a causal relationship exists, it has been proposed that pathological bursting may disrupt transmission and processing of motor-related activity transmitted by upstream nuclei. Several hypothesized causes of phase-locked bursting involve dendritic processes and the interaction between intrinsic and synaptic currents. The generation of bursts in STN neurons has been attributed to the presence of dendritic Ca2+ channels and their increased availability following inhibitory post-synaptic potentials triggered by incoming GPe spikes. Synchronization then arises by means of feedback inhibition from the reciprocally connected GPe, mediated by a reduced level of incoming striatal movement-related activity, caused by a loss of dendritic spines in these cells.

To investigate this hypothesis, we have developed a new model of basal ganglia circuits incorporating the interaction between dendritic intrinsic and synaptic currents to explore the conditions underlying the emergence of phase locking in the STN-GPe loop.
To take into account dendritic processing, our model consists of morphologically detailed cell models for the GPe and STN that have non-uniform distributions of active ion channels in their dendritic trees [3,4]. To model the interaction between these channels, underlying intrinsic currents, and synaptic currents synapses exhibiting short-term plasticity on realistic time scales were placed in regions in the dendritic tree based on the available experimental literature. The model is used to investigate the generation of pathological oscillations and circuit interventions that disrupt phase locking, reversing the decoupling of STN-GPe loop activity from incoming motor activity and possibly leading to a partial restoration of normal motor processing.

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PII.13 An automatic procedure for the accurate extraction of the sEMG envelope

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University Roma TRE

INTRODUCTION: The standardization of the methods used for the extraction of the sEMG envelope is a problem yet to be solved. The most used procedure relies on a low pass filtering of the rectified version of the raw signal; in this context, a non-optimal choice of the time constant for the filter can worsen the results of the analysis. In literature, several proposals for an adaptive algorithm for sEMG amplitude estimation have been presented; in this work, an update to an iterative algorithm previously developed [1] is presented, defining an information-based, point-by-point convergence criterion that has allowed for a full automatization of the estimation process.

METHODS: The sEMG processing scheme used in this work is composed by a prewhitening filter, a 2nd order detector, a smoothing filter and a relinearizer. Our adaptive procedure aims to find the optimal, point-by-point window length for the filtering block. The behaviour of the algorithm is based on the modelling of the signal as a modulated white gaussian process. The iterative procedure works via the estimation of the envelope and its first two derivatives; at each iteration step, the sample by sample entropy is evaluated. The convergence step is defined as the first stationary point of the entropy/iterations curve; the convergence test is applied independently on each sample, as to allow a different number of iterations for each point of the envelope.

RESULTS: The performance of our method has been evaluated on a set of simulated signals, generated by the modulation of a white gaussian noise series with different modulating waveforms. The fraction of variance unexplained (FVU) by the envelope estimated with both our method and the typical procedures adopted in literature have been computed for comparison purposes. The iterative procedure has been able to converge in a maximum of 10 iterations; in addition, for all the modulating shapes used in the study, the adaptive procedure has yielded the best approximation (i.e. lower FVU values) of the true waveform, with respect to any fixed length filtering approach.

CONCLUSIONS: The proposed adaptive algorithm has been shown to yield better estimation performance with respect to the filtering procedures that are used for sEMG analyses in literature. Our method does not require any operator-dependent choices, due to the fact that it does not require any a priori knowledge on the features of the true modulating waveform. The results from the performance analysis support the proposal of this algorithm as a standard means for the extraction of the sEMG envelope, so improving the repeatability and the reliability of its related analysis.

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PII.14 Advancements in Rapid Calibration of Dynamic EMG-Force Models at the Hand/Wrist Using a Minimum Number of Electrodes

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BACKGROUND: The association between EMG standard deviation (EMGσ) and muscle force is used in various applications, including: “direct” control of myoelectric prostheses, clinical biomechanics and ergonomics analysis. Advanced models of the EMGσ-force relationship calibrate subject-specific dynamics based on force-varying training sets using time durations of upwards of 1-2 minutes. For one degree of freedom (1-DoF) hand-wrist contraction, we studied the duration of data required to train dynamic models as well as the need for subject-specific models. Shorter training would be advantageous for all applications. We also studied the relationship between estimation error and the number of electrodes.

METHODS: For 9 healthy subjects, 16 conventional bipolar electrodes were mounted circumferentially about the proximal forearm. The hand was secured to a load cell to measure wrist extension-flexion, radial-ulnar deviation or pronation-supination forces. The fingers were secured to a second load cell to measure hand open-close. A screen target produced 38 s duration random, uniformly distributed, dynamic (0.75 Hz, white, bandlimited) force targets along one of these four contraction dimensions per trial. Effort ranged over 0-30% MVC. Separately for each subject; linear, FIR (20th order), 1-DoF regression models relating EMGσ to force were trained using 2 trials. Initially, all 16 electrodes were used as inputs. Thereafter, backward stepwise selection of the training data sequentially reduced the number of electrodes. RMS error on two separate test trials was evaluated at each step. Training duration was then progressively decreased. Finally, a “universal” fixed dynamic model that was not subject-specific (except for each electrode gain) was compared to models with subject-specific dynamics.

RESULTS: Using all 76 s of training data for calibration, each DoF found that stepping down to fewer than two electrodes was unacceptable, and retaining more than two electrodes provided limited benefit. This result was expected and consistent with existing prosthesis practice. With 2 electrodes, the average test error ranged from 8.3-9.2 %MVC, depending on the DoF. Error increased as the training duration decreased, particularly for durations less than one full trial (38 s). With just 6 s of training data, the average test error was 13-16 % MVC. Average errors were nearly identical when this entire process was repeated with a fixed, universal dynamic filter (and, thus, only a zero-order gain was fit via regression). Additionally, the approach using a universal filter selected similar electrodes via the backward stepping procedure.

CONCLUSION: For these experimental conditions, all subjects shared similar dynamics. Thus, a simple, more robust (parsimonious) system identification procedure was found in which only channel gain required training. With our approach thus far, substantial duration training trials are still required. Funding: NIH 2R42HD076519.

PII.15 Relationship between fractal dimension and firing rate slopes in quadriceps muscle during fatiguing contractions

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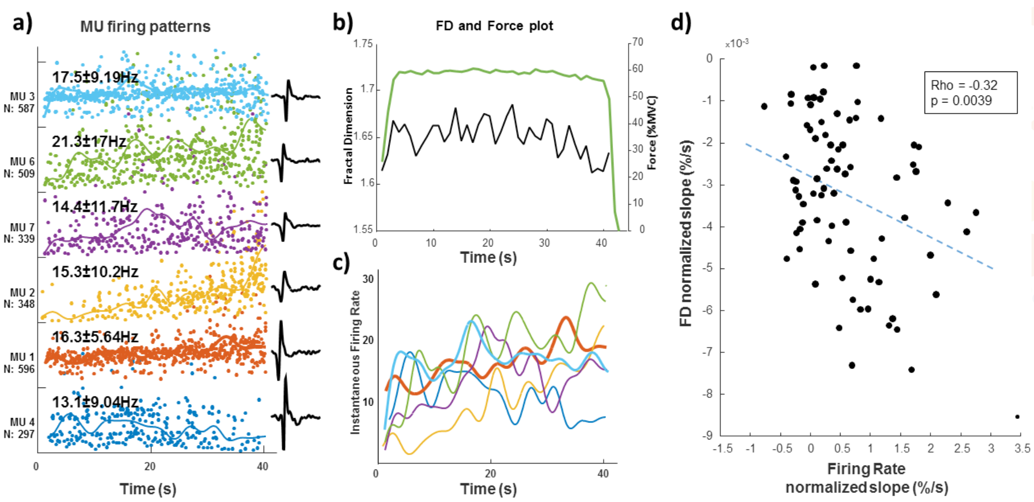
BACKGROUND AND AIM:. Myoelectric fatigue has been studied extensively using different parameters extracted from EMG signals (e.g. muscle fiber conduction velocity, mean power frequency, high order statistics). Recently fractal dimension of EMG signals was proposed as an index of central fatigue, as it is related to the synchronization of the firing patterns of the active MUs. The aim of the present study was to investigate if the slope of FD during fatiguing contractions was correlated with the increase of firing rate of the active motor units.

Methods: A dataset of EMG signals collected in previous experiments was used for this study. The database included EMG data from 70 subjects. Subjects were sitting on an ergometer were asked to perform isometric leg extension with the knee flexed at 120 degrees. EMG signals were detected in monopolar configuration from Vastus Medialis and Vastus Lateralis muscles of left and right leg using bidimensional arrays of 32 electrodes with 8mm IED (Spes Medica, Italy). Signals were decomposed using the decomposition tool implemented in the OTBiolab software (OTBioelettronica, Torino, Italy) (see figure a). The parameters set for the algorithm were the same for each signal and were selected on preliminary tests on a subportion of the dataset. The instantaneous firing rate of the identified motor units was extracted and linear regression was applied to identify initial value and slope (see figure c). Fractal dimension was computed for each channel and time epoch of 1s (see figure b). The average value among all channels was computed and linear regression was applied to obtain initial value and slope. Pearson correlation coefficient was applied to evaluate the correlation between slope of FD and firing rate.

RESULTS: The decomposition algorithm identified in average 3.5 motor units in 122 signals, with an average number of 562 firings for each identified MU. The firing patterns were visually inspected in order to remove duplicates or incorrect results. The total number of analysed signals was 84. A significant correlation was observed between slope of FD and slope of firing rate of the active motor units (see figure d).

CONCLUSIONS. Fractal dimension of EMG signals is sensitive to changes of firing rate during fatiguing contractions, thus it could be used as a tool to evaluate central nervous system changes, as it does not require large bidimensional arrays or decomposition algorithms.



PII.16 Scanning-EMG masked least-squares averaging from multiple-discharges recordings

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BACKGROUND AND AIM: Scanning-EMG allows to investigate the motor unit (MU) architecture by recording the motor unit potential (MUP) in different spatial locations across a linear corridor (scanning-MUP). When a single MUP discharge is recorded at each position, median filtering in the spatial dimension is frequently used to remove MUP artifacts in scanning-MUP. A recently developed technique allows a more refined filtering based on a masked least-squares smoothing (MLSS) of the scanning-MUP in the spatial dimension. The scanning-EMG technique can also record multiple discharges at each recording position. Mean and median have been traditionally used for averaging these multiple discharges of scanning-EMG. These averaging techniques can be followed by the above mentioned filtering in the spatial dimension to further enhance the quality of the signal. The aim of this work is to present a new technique that operates simultaneously among discharges and in the spatial dimension.

METHODS: We propose a new technique that simultaneously performs both the averaging of the individual discharges and the masked least-squares spatial filtering: the multi-MLSS (MMLSS) algorithm. The aim is to combine the effectiveness of MLSS filtering with the robustness of taking into account the information from multiple discharges at each recording position. The new method operates in three consecutive steps. Firstly, the individual artifact mask is calculated for each discharge in each position of the recording (note that a different number of discharges per recording position is allowed), by thresholding the difference between the individual discharges and a preliminary median-filtered scanning-MUP; allowed mask values are 1 for valid samples and 0 otherwise. Secondly, the information of the different discharges is combined at each spatio-temporal position: the overall mask is calculated by adding the mask values at each position, and the average scanning-MUP signal is calculated by weight-averaging the discharge samples, where weights are the individual artifact mask values. Finally, MLSS is applied to the averaged signal with the overall mask.

RESULTS: The new MMLSS algorithm is tested both in simulated and real signals, and compared to both single-discharge methods (median filter and MLSS) and multiple-discharge methods (mean-median, median-median).

RESULTS show an enhancement of the SNR of the post-processed signal up to 20 dB in noisy environments with moderate muscle contraction. When compared to single-discharge techniques, the additional information provided by multiple discharges leads to a 6 dB SNR gain over the second-best method (MLSS). When compared to multiple-discharges techniques, the masked least-squares procedure leads to a 4 dB SNR gain over the second-best method (median-median).

CONCLUSIONS: The proposed method outperforms all previously available methods in all tested recorded conditions, allowing to retrieve a more reliable scanning-MUP waveform.

PII.17 Automatic High Density Surface EMG Decomposition in Amyotrophic Lateral Sclerosis and a Novel Validation Method

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BACKGROUND AND AIM: This study aims to evaluate the performance of automatic progressive FastICA peel-off (APFP) for decomposition of surface electromyogram (EMG) signals of amyotrophic lateral sclerosis (ALS) patients.

METHODS: A total of 84 trials of high density surface EMG signals were recorded from the first dorsal interosseous (FDI) muscle of 9 ALS subjects, using a protocol analog to clinical EMG examination. To evaluate the performance, a novel two-source validation method was developed by dividing the 64 channels of ALS data to the sparse data set and the interference data set. The sparse data were decomposed by expert visual inspection while the interference data were independently and automatically decomposed by the APFP framework.

RESULTS: The agreement of the decomposition yield from the two data sets was examined. An average of 9.1±3.3 motor units were extracted from each trial of high density surface EMG signals. Twenty-two trials of high density surface EMG signals were determined suitable for two-source validation, where 34 common motor units were extracted with an average matching rate of 99.18 ± 1.11%.

CONCLUSIONS: This study demonstrates application of the APFP framework for automatic decomposition of high density surface EMG signals from diseased muscles. More importantly, taking advantages of the signal characteristics of ALS patients, this study has developed a novel two-source validation method to assess the decomposition performance. The high matching rates of the common motor units obtained from the two data sets provide a supportive evidence of the reliability of the APFP framework for automatic surface EMG decomposition.

PII.18 Classification Accuracy of Different Machine Learning Algorithms for Human Activity Recognition

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AIM: the purpose of this study is to compare different classification algorithms for human activity recognition. The classification techniques implemented and compared in this study are k-nearest neighbour (kNN), artificial neural networks (ANN), support vector machines (SVM), Naïve Bayes (NB), and Decision Tree (DT). Activities were performed using one body-worn miniature magnetic and inertial measurement unit (MIMU).

METHODS: 8 activities were performed and classified, namely sitting, standing, lying down on the back, level walking, ascending and descending stairs, uphill and downhill walking. The experimental setup consisted of one MTx MIMU sensor by Xsens Technologies, located on external side of the right thigh. MTx has a triaxial accelerometer, a triaxial gyroscope, and a triaxial magnetometer. The MIMU acquires acceleration, rate of turn, and Earth-magnetic field data. The activities were performed in an outdoor area. A group of 15 healthy subjects (8 males, 7 females) performed the activities without restrictions in speed and style of performing. Activities were recorded in a random way. Each activity lasted 20 s and was repeated 25 times. Signals were recorded with a sampling frequency of 100 Hz. The 9 signals were segmented through a 5-s sliding window and, from each segment, features in Time-domain, Frequency-domain, and Wavelet Transform were extracted. The 38 features extracted were: mean value, variance, standard deviation, skewness, kurtosis, minimum and maximum values, 11 samples from the autocorrelation sequence, mean frequency, median frequency, Shannon spectral entropy and the norms of Approximation and Detail coefficients at 7 level of decomposition of Discrete Wavelet Transform. Thus, every 5 s, 342 (9 x 38) features were extracted. The available features were then normalized to give each feature the same weight. To reduce redundancy of information and to eliminate useless features, a Genetic Algorithm (GA) was used to find the most discriminant subset of features. 69 features were selected from GA and used as input of the different classifiers. Classifiers were trained on 10 subjects. For each subject only 10% of the windows were randomly selected and then included in the training set. The remaining windows were used as test set.

RESULTS: to compare the classifiers, three different validation techniques were used: a) 5-fold crossvalidation on the training set, b) validation on the test set, c) and performance on each of 15 subjects involved in the study. The performances of the five classifiers for each validation were: kNN: a) 93.38%, b) 97.03%, c) 96.70% ± 2.13% ANN: a) 90.72%, b) 95.79%, c) 95.64% ± 2.22% SVM: a) 91.85%, b) 96.61%, c) 96.58% ± 2.13% NB: a) 91.53%, b) 96.46%, c) 96.14% ± 3.33% DT: a) 86.00%, b) 90.99%, c) 89.47% ± 4.62% CONCLUSION: the best classification algorithm, for this kind of activities and position of the sensor unit, was kNN.

Table 1: classification accuracy of different classifiers.

Classifier	5-fold crossvalidation (%)	Test Set (%)	Per subject (%)
kNN	93.38	97.03	96.70 ± 2.13
ANN	90.72	95.79	95.64 ± 2.22
SVM	91.85	96.61	96.58 ± 2.13
NB	91.53	96.46	96.14 ± 3.33
DT	86.00	90.99	89.47 ± 4.62

PII.19 Validation of inertial measurement unit to assess shoulder movement during complex lifting tasks

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BACKGROUND AND AIM: Motion capture systems are the gold standard for precise measurement of human movements during complex tasks. These systems lack portability however, and can only be used in laboratory settings. Recent improvement in inertial measurement units (IMU) hardware and software have made these systems a potentially good alternative to quantify human movement outside of the laboratory, i.e. in more ecological settings where participants are more likely to use natural movement strategies. IMUs have been validated in several contexts and for different joints, including the shoulder. However, the majority of tasks used for shoulder validation focused on simple planar movements. Yet, during activities of daily living, most shoulder movements require more complex movements in 3D-space. The aim of this study was therefore to test the criterion validity of an IMU system compared to a camera-based motion capture system to assess shoulder movements during complex upper limb lifting task.

METHODS: Data were collected using VICON system (7Mx T20 and 2 MxT10 cameras) and Xsens system (MVN Awinda). Shoulder joint excursions were estimated based on their respective biomechanical models: Kingait (Vicon) and ISB modify (Xsens). First during simple shoulder movements (humeral flexion, scaption and abduction) performed with different trunk positions, and second during standardized simulated lifting tasks using the standardized Valpar Component Work Sample 19 test. Participants had to lift trays of different weights (2.2kg, 6.8kg, 13.6kg and 22.7 kg) at different heights (0.45m, 1.2m and 1.73m). Each participant performed a total of 32 movements. Correlation coefficients between arm movements measured by Xsens and by VICON were calculated for each movement axis (sagittal axis - X: vertical axis - Y; frontal axis - Z). Root mean square error (RMSE) was also calculated.

RESULTS: Sixteen healthy subjects participated in this study (8 men, 12 right-handed, mean age of 26.4 years). Correlation coefficients were high for all three axes for the simple movements (X: $r = 0.96 \pm 0.04$; Y: $r = 0.87 \pm 0.19$; Z: $r = 0.92 \pm 0.12$) as well as for the lifting tasks (X: $r = 0.92 \pm 0.10$; Y: $r = 0.88 \pm 0.07$; Z: $r = 0.83 \pm 0.06$). RMSE was large across axes, being quite high in the Y and Z axes for both the simple movements (X: 8.5°± 4.6°; Y: 44.3°± 9.7°; Z: 31.7°± 9.1°) and the lifting tasks (X: 9.5°± 8.4°; Y: 43.1° ± 14.4°; Z: 33.4°± 9.4°).

CONCLUSIONS: The correlations between the Vicon and the Xsens were good to excellent during simple shoulder movements and standardized simulated lifting tasks, while RMSE was moderate to large, suggesting that the IMU system is valid/reliable but that angular values obtained differ from that of a camera-based system. The different biomechanical models used for anatomical reconstruction during data analysis is likely a major contributor to this difference, especially at the shoulder.

PII.20 Effects of vibrotactile stimulation on force steadiness on the behavior of motor units of the first dorsal interosseous muscle

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BACKGROUND AND AIM: Neurophysiological control of voluntary movements is ultimately influenced by sensory feedback from cutaneous, muscular and articular afferents. An intriguing phenomenon involving this feedback system is the enhancement of motor performance by the application of optimal stimuli on sensory receptors. Although recent studies have shown improvements in posture and force control, few studies explored how optimal vibrotactile stimulation would influence the neural drive to the muscle. Here we aim at investigating the effects of an optimal cutaneous vibration on the activity of a population of motor units (MUs) of the first dorsal interosseous (FDI) muscle.

METHODS: Eleven healthy young adults performed visuomotor tasks that consisted of steady abduction contractions of the index finger at 2.5% and 5% of the maximal voluntary contraction (MVC) force. During the contractions, vibrotactile stimuli at a frequency of 175 Hz were applied to the radial surface of the metacarpophalangeal joint at varying amplitudes. Additionally, a control condition without vibration (CTR) was evaluated. The vibration amplitude corresponding to the best force steadiness was considered as the optimal vibration (OV). Contractions lasted 45s, and each condition (force level and vibration intensity) was repeated three times. Trials were performed in a randomized order. The electrical activity of the FDI was recorded with a high-density surface EMG grid of 64 electrodes, and the MU spike trains were extracted using an automatic decomposition algorithm. Motor performance was estimated as the coefficient of variation (CV) of force. The CV of interspike intervals (ISIs) and mean MU discharge rate (DR) were also evaluated.

RESULTS: No significant interaction of vibration and contraction intensity was found for any of the variables ($p = 0.264$, $p = 0.361$, $p = 0.278$ for force CV, MU discharge rate and ISI CV, respectively). OV significantly decreased force CV (4.13±0.59% vs. 3.52±0.43%, $p = 0.001$). A total of 978 MUs was decomposed (2.5%MVC: 271 MUs for both CTR and OV; 5%MVC: 279 and 277 MUs for CTR and OV, respectively). The improvement in motor performance as a result of OV was followed by a significant decrease in the global MU DR (12.53±0.97Hz vs. 12.23 ±0.85Hz, $p = 0.026$) and ISI CV (19.75±1.71% vs. 18.74±1.44%, $p = 0.001$). Nevertheless, the DR of tracked MUs (N=56) increased with OV (6.38±0.59Hz vs. 6.96±0.60Hz, $p = 0.002$).

CONCLUSIONS: An improvement in force steadiness with vibrotactile stimulation was observed along with a decrease in the global DR of the detected MUs. Moreover, vibration increased the DR of the already recruited MU, thereby decreasing the ISI CV. We interpret these findings as being a result of greater excitability of the motor neuron pool during OV in comparison with CTR. This enhanced excitability would cause the recruitment of high-threshold MUs, as well as the increase in the DR of previously recruited MUs.

PII.21 Relationship between isometric muscle force and fractal dimension of surface electromyogram in the biceps brachii muscle

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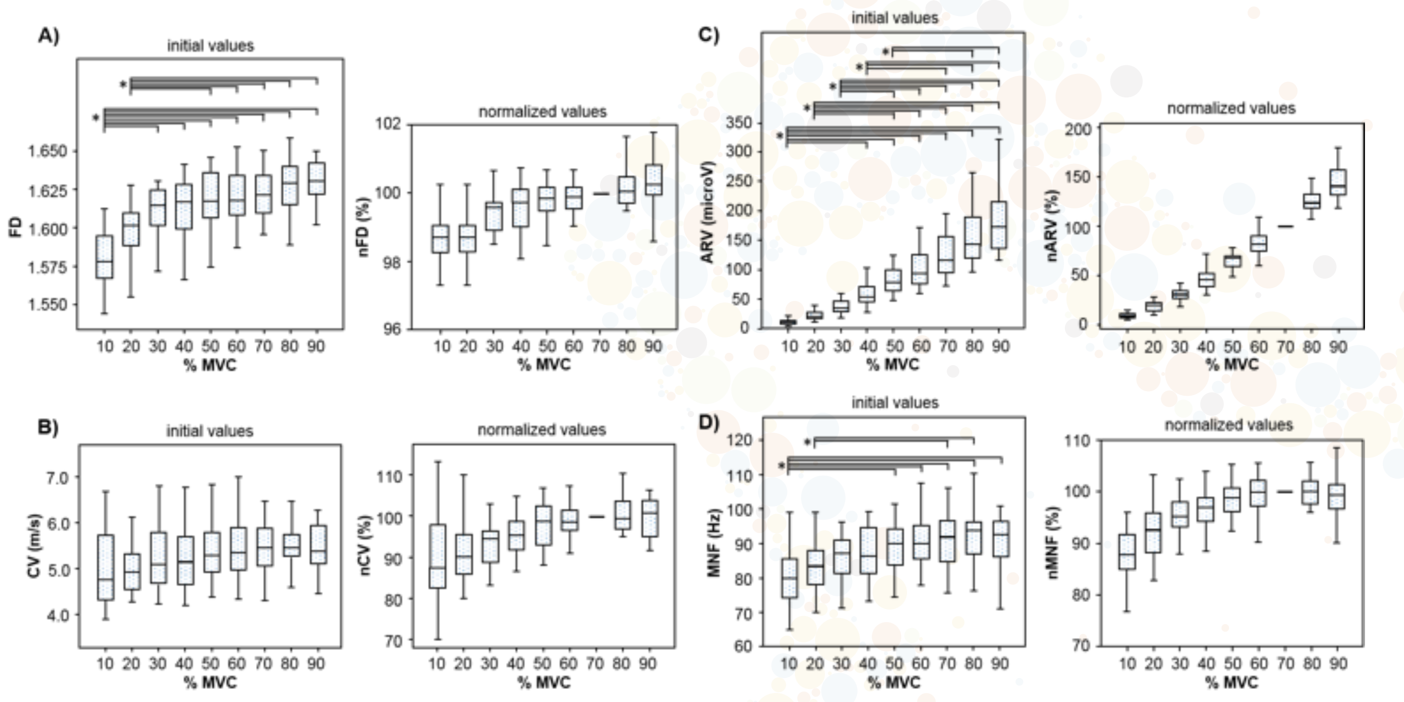
BACKGROUND AND AIM: The relationship between fractal dimension (FD) of the surface electromyogram (sEMG) and the intensity of muscle contraction is still controversial in simulated and experimental conditions. To support the use of fractal analysis to investigate myoelectric fatigue, it is crucial to establish the interdependence between FD and muscle contraction intensity. Thus, the aim of this study was to determine if a relationship between force and FD of the sEMG during isometric contractions of the biceps brachii muscle exists.

METHODS: We analyzed the behavior of FD, conduction velocity (CV), mean frequency of the power spectrum (MNF) and average rectified value (ARV) in twenty-eight volunteers at nine levels of isometric force. Myoelectric signals were detected in monopolar configuration, using bidimensional arrays of 64 electrodes positioned on the biceps brachii muscle. Initially, two isometric MVCs were performed, separated by 2 min rest. After 4 min rest, the subjects performed a sequence of nine short contractions, from 10 to 90% MVC in steps of 10% MVC in randomized order, lasting 5 s, with 20 s of rest in between.

RESULTS: Median scores of FD, MNF and ARV were statistically different across the nine levels of force ($p < 0.0001$). The post-hoc analysis revealed statistically significant differences in the considered parameters obtained at low force levels (respectively 10-40% MVC for ARV and 10-30% MVC for FD and MNF) with respect to high force levels (50-90% MVC), and are presented in the figure (* $p < 0.001$). However, the values of FD and MNF increased with force until a plateau was reached at 30% MVC (Figure A and D).

CONCLUSIONS: Overall, our findings suggest that above a certain level of force, the use of FD to evaluate the myoelectric manifestations of fatigue may be considered, regardless of muscle contraction intensity.



MOTOR CONTROL

PII.22 Proximal upper limb muscles outperform distal limb muscles when learning the same motor task

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BACKGROUND AND AIMS: We recently reported large improvements in task accuracy on a novel motor training task performed using glenohumeral movement. Both skill acquisition and retention appeared to be greater than improvements reported in previous studies using the same motor learning task with the distal upper limb muscles (Andrew, et al., 2015; Dancey et al., 2014). This study thus aimed to compare task performance between the proximal and distal upper limb. In addition to hypothesized differences between the proximal and distal upper limb muscles, previous research in the field of motor development and motor control has shown large sex-based differences in task performance. During early motor development, gross motor skill development is often encouraged in males, through sport participation and rougher play, while emphasizing fine motor skills for females. This can lead to males outperforming females on gross motor tasks, potentially due to increased muscle mass and neural control of the upper limb. Therefore, the second aim of this study was to assess any sex-based differences in motor performance on both the distal and proximal tracing tasks. The first hypothesis for this study, was that all participants would perform better at the proximal muscle tracing task, compared to the distal tracing task. The second hypothesis for this study was that due to increased control over the proximal upper limb muscles, males will outperform females on the proximal task.

METHODS: 44 right handed participants were recruited from the University of Ontario Institute of Technology. 24 participants completed 20 trials of a novel motor tracking task consisting of tracing a sinusoidal waveform randomly varying in amplitude and frequency and with a range of complexities, using their shoulder as the prime mover, while holding their thumb rigid, and the remaining 20 participants completed the same task using their thumb, while holding their upper arm rigid. Error is expressed as percent of distance from the ideal trace.

RESULTS: Significant differences in baseline accuracy (204.9% error ± 50.5% SD vs 98.9% error ± 22.1% SD ($p<0.0001$)) were seen between the proximal and distal tasks, with the shoulder group significantly outperforming the thumb group. Both groups improved significantly from baseline ($F[2,39]=76.95$, $p<0.0001$), with a significant interactive effect of group, with the shoulder group significantly outperforming the thumb group at every stage of task performance ($F[2,39]=11.58$, $p<0.0001$).

CONCLUSIONS: No significant sex-based performance differences were seen within the distal tracing group. While both sexes improved significantly from baseline within the proximal group, males performed significantly better vs females at baseline, which followed through to retention on the proximal task, indicating a potential male advantage to gross motor tasks.

PII.23 The Reliability of TMS-Derived Indices of Corticomotor Inhibition and Corticospinal Excitability in Two Distinct Populations

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Introduction: Transcranial magnetic stimulation (TMS) allows the quantification of cortico-cortico and corticospinal excitatory and inhibitory mechanisms, responsible for motor skills.[1] Day-to-day reliability of corticomotor inhibition and corticospinal excitability has large ranges (fair-to-excellent)[2-5] which may, in part be due to the type of population assessed. Recently, we demonstrated increased corticomotor inhibition in soccer players following ball heading[6] but are unaware of TMS reliability in this population. Therefore, to establish effects of TMS reliability in soccer players and for less homogenous populations, we aimed to compare trained soccer players vs recreationally active populations. We did this by measuring inter-day reliability of corticomotor inhibition and corticospinal excitability, assessed from the lower limbs. Methodology: Thirty-nine participants were separated in Group A (soccer players, n=19, 5 females, age 22 ± 3 y) and Group B (recreationally active, n= 20, 4 females, age 24 ± 4 y). Corticomotor inhibition and corticospinal excitability were recorded using TMS during two testing sessions, spaced 1-2 weeks apart. Inter-day reliability was quantified by using intra-class correlation coefficients (ICC) and coefficients of variation (CV).

RESULTS: Corticomotor inhibition was not different between populations (p> 0.05), with good overall reliability (ICC = 0.68 ± 0.07; CV = 6.78 ± 3.23). Corticospinal excitability in group A was significantly lower than group B (45.1 ± 20.8 vs 81.3 ± 39.7 %Mmax, p< 0.0001), with good reliability (ICC = 0.66 ± 0.07; CV = 21 ± 5.23 %).

CONCLUSION: Although corticomotor inhibition and corticospinal excitability are stable and maintain a good degree of reliability when assessed over different days, the former displays slightly better inter-day reliability values. Furthermore, the levels of excitation in the two groups suggests that this measure may differ depending on specific population groups, and as such may not be appropriate for inter-group comparisons of corticospinal excitability.

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PII.24 Chiropractic Manipulation Increases Maximal Bite Force in Healthy Individuals

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BACKGROUND AND AIM: The relationship between sensory input and the muscle activity has been studied in various muscles and nerve groups on the masticatory system. In several animal studies, the reduction of the facilitation of the masseter muscle was shown when the sensory feedback from the periodontal receptors was removed, indicating the importance of the peripheral feedback systems in controlling masticatory muscles activity. Manipulation of those sensory systems, e.g. by spinal manipulation, might also affect the mastication and bite. The spinal manipulation by chiropractic application can modify the sensory feedback mechanism and alter the biting process. Although the biting force of various animals, including humans, has been investigated using different techniques, researchers usually used two or more teeth to measure the maximal bite force in humans. Ideally, however, measuring total bite force where all the teeth can contribute must be investigated to determine the strength of the jaw closing force. The focus of this study was to find out a possible relationship between maximal bite force and the spinal manipulation applied by chiropractic treatment professionals.

METHODS: To obtain maximal bite force, a strain gauge was used which was placed under the tungsten bite plates. Express STD Vinyl Polysiloxane impression material was used as a mold which was glued on both sides of the tungsten plates for allowing all teeth to take part in the bite attempt. In each session, the subject was asked to bite the mold as much as s/he could with verbal encouragement from one of the researchers. Each subject bit the mold three times for 3 seconds with an interval of one minute between each bite attempts. Then, chiropractic care consisting of the neck and back spinal adjustments (SM group- by a doctor of chiropractic) or sham manipulation (control group-by one of our colleagues without any chiropractic experience) was performed which lasted about 15 minutes. Then peak-to-peak values of each bite force record were measured.

RESULTS: The mean maximal bite force was significantly different between pre- (M=457.46 Newtons, SEM=33.54 Newtons, N=14) and post- (M=496.75 Newtons, SEM= 30.44 Newtons, N=14) groups (p=0.0192), providing evidence that the chiropractic manipulation is effective in increasing the maximal total bite force. The same test was performed to determine whether there was a placebo effect in SM. The mean maximal total biting force was not significantly different between pre- (M=405.61 Newton, SEM=33.83 Newton, N=14) and post- (M=398.22 Newton, SEM=37.09 Newton, N=14) groups (p=0.2044), showing that sham intervention has no significant effect on maximal total bite force.

CONCLUSIONS: This study demonstrates that SM increased subjects' maximal bite force significantly. On the other hand, the sham application had no significant effect on the maximal biting force.

PII.25 Interplay Between Body Sway and Intrinsic Foot Muscle Activation for Postural Balance Control in Humans

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BACKGROUND: The intrinsic foot muscles (IFM) are believed to contribute to balance during postural tasks while stabilizing the foot. However, the interaction between body sway and IFMs activation has never been investigated before. Recent work has shown that assessment of the temporal organization (or structure) of variability in EMG signals and centre of pressure (CoP) can provide insight into the degree of challenge a task poses to the sensory-motor system. Here we use a measure of the time scale over which structure persists, Entropic HalfLife (EnHL), to identify if similar changes in IFM EMG signal properties and CoP data occur in response to different postural balance control challenges.

METHODS: A 64 channel surface electrode array was used to record EMG from the plantar region of the foot from seventeen healthy participants (weight: 74.3 ± 14.3 kg, height: 175.7 ± 9.4 cm). CoP trajectories were also recorded with a force plate, where participants stood while performing: two-foot; one-foot and two-foot tiptoe stance. Total intensity of wavelet transformed EMGs and CoP medio-lateral and anterior-posterior trajectories were used to calculate EnHL, by calculating the sample entropy of signals resampled over increasing time scales. EnHL identifies the time scale at which the signal transitions from structured to random, with longer EnHL indicating structure is maintained or persists over longer time periods.

RESULTS: Medio-lateral CoP EnHL was shortest for one leg stance (121.6 ms) and similar between two foot stance (209.6 ms) and two foot tiptoe (216.5 ms), so posture was most variable in this direction during one foot standing. Anterior-posterior CoP EnHL was shortest for two foot tip toe (146.5 ms) and got progressively longer between one foot stance (188.4 ms) and two foot stance (260.2 ms). This indicates that posture became more unstable, or variable, across these conditions. In contrast IFM EMG EnHL was longest for two foot tiptoe (22.8 ms) and became progressively shorter from one leg stance (17.5 ms) to two foot stance (12.5 ms). This suggests EMGs became more structured and less random as the challenge to maintain balance increased. Therefore as anterior-posterior CoP became more variable, the EMG signals became more structured.

CONCLUSION: There was an increase in drive to the IFMs in the more challenging tasks (one-foot stance and two-foot tiptoe), whereas an increase in variability of CoP trajectories occurred. This suggests that the postural control system was subject to more frequent intervention during the more challenging balance tasks, with the EMG data suggesting that activation of IFMs contributed to this process. IFM activation therefore contributes to postural stability, particularly during more challenging balance tasks.

PII.26 Characterizing forearm muscle recruitment patterns during radial and ulnar rotation of the wrist using a haptic wrist robot

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Background and Aim: Most hand and wrist motor tasks conducted during daily living are executed via a combination of wrist flexion/extension, radial/ulnar deviation, and supination/pronation of the forearm. However, while investigations have been conducted on the muscular contributions to wrist flexion/extension and forearm supination/pronation during isometric experimental protocols, there has been minimal focus bestowed upon radial and/or ulnar deviation of the wrist; particularly during dynamic movements.

METHODS: 11 healthy males participated. Surface electromyography (sEMG) was recorded from eight muscles on the right upper extremity: flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), extensor digitorum (ED), biceps brachii (BB) and triceps brachii (TB). Participants were seated with their right arm supported by a three degrees of freedom wrist manipulandum (WristBot, Genoa, Italy) with the hand firmly grasping its handle. The robotic device exerted forces through the handle, in either a radial or ulnar direction (ROM ±30°; angular velocity 15°/sec). This was performed in three forearm positions: 1) 30° supination, 2) neutral, and 3) 30° pronation. Force was applied in two directions (radial or ulnar), resulting in six randomized conditions. For all conditions, a force of 15% of maximum wrist extension was produced by the robot. Six repetitions, consisting of both a concentric and eccentric phase, was performed for each condition. Angular velocity was controlled as participants were required to track a moving target on a computer screen that corresponded to the robot handle position. The robot compensated for weight and inertia during movements. Muscle activity was linear enveloped (3Hz Butterworth cut-off), normalized to muscle-specific maximal voluntary contractions (MVC) and angular position determined concentric and eccentric movements.

RESULTS: The wrist extensors were significantly more active than the wrist flexors ($p<0.05$), with average muscle activity exceeding 10% MVC across most conditions. Interestingly, the most inactive muscle was the FCR, which never reached more than 2.5% MVC. In contract, the ECU produced 27.5% MVC during the pronated forearm posture with radial deviation. Four muscles demonstrated an effect of forearm rotation, with the FCU and BB producing more sEMG activity in supination than pronation ($p<0.05$). The ECU and TB were most active in pronation while the least active in supination.

CONCLUSION: These results suggest that the wrist extensors are more active during radial and ulnar wrist movements than the wrist flexors. In a pronated posture, ECU is the primary moment generator and this role may change across forearm postures. Future work will partition muscle roles into moment generators and stabilizers, which may help provide insight into overuse injury risk and targeted rehabilitation protocols.

PII.27 Decreased Cortical White Matter Integrity in Patients with Degenerative Cervical Myelopathy- A Diffusion Spectrum Imaging Study

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Background and Aim: Patients with degenerative cervical myelopathy (DCM) is common cervical degenerative disorders involving spinal cord lesions. Patients demonstrate multiple symptoms and signs, including sensory, motor, control, and cognition related complain. Decompression surgery is recommended for moderate and severe cases, and conservative treatment for mild cases. Pathological biopsy has revealed changes in the posterior and lateral columns and / or anterior gray matter. Wallerian degeneration was found in ascending and descending pathways.[1] The technology of Diffusion Tensor imaging MRI had been developed to quantify integrity of nerve fibers and demonstrate lesion in white matter in spinal cord. Whether the axonal fibers in the brain are involved are unclear. The development of diffusion spectrum imaging (DSI) has demonstrated advantage over tensor-based tractography in its ability to trace crossing fiber pathways. We use DSI to investigate microstructural integrity of the fiber tracts. in the brain. The purpose of this research is to investigate the integrity of fiber tracts in the brain in patients with degenerative cervical myelopathy Methods Participants were recruited from the neurosurgery clinic at National Taiwan University Hospital. They were diagnosed based on relevant imaging and symptom/signs. DSI was used to study the tract integrity of axonal fibers.[2] The generalized fractional anisotropy (GFA) values of white-matter tracts were computed to represent microstructural property of each tract. Tract-based automatic analysis (TBAA) was used to produce integrity profiles of 76 fiber tracts in the brain. Threshold Free Cluster Weighted (TFCW) scores were used for group comparison. For every step of individual tract, a linear regression was used to remove the effects of age and sex. We calculated the effect size of each step between groups, then estimated weighted scores for screening the most different tract steps among the two groups.

RESULTS: 8 patients with cervical degenerative myelopathy and 8 aged matched participants were recruited (Table 1). Specific step of a specific tract with significant difference comparing the GFA value of patients with that of asymptomatic participants were indicated by a Connectogram (Figure). Green indication decreased GFA, while red indicating increased in patients. These changed tracts included cortical spinal tract (CST) and thalamic radiation (TR), and commissure fibers (Table 2).

CONCLUSION: Patients with degenerative cervical myelopathy demonstrated decreased white matter integrity of the association, projection, and commissure fibers, which relating sensorimotor performance.

PII.28 Immediate change in electromyographic activity after different types of trunk muscle exercises

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Introduction: The trunk muscles are classified into superficial and deep. Hence, different types of exercises are needed to facilitate each trunk muscle in the clinic. However, the immediate effect of each trunk muscle exercise on muscle activity is unclear. The purpose of this study was to examine the effect of different types of trunk muscle exercise on the activity pattern of the trunk muscles during breathing and pelvic tilt movement.

Method: Fourteen healthy men agreed to participate in this study. All participants performed trunk side flexion in side-lying position and abdominal draw-in in supine position using cross-over design. Surface electrodes were attached to the rectus abdominis (RA), external oblique (EO), internal oblique/transversus abdominis (IO/TrA), lumbar erector spinae, thoracic erector spinae, sternocleidomastoid, and scalene on the right side. Surface electromyography (EMG) was performed before and after each intervention during the following experimental tasks: maximum inspiration/expiration and maximum pelvic anterior/posterior tilt in standing. Additionally, the muscle activity during each intervention was monitored. The EMG activity was normalized as a percentage of the activity during maximum voluntary contraction for each muscle (%MVC). The %MVC during each intervention was analyzed using one-way analysis of variance (ANOVA) to compare between muscles. Two-way ANOVA was used to compare the muscles activity before and after intervention ($p<0.05$).

Result: The IO/TrA activity (44.7±22.3 %MVC) was significantly greater than that of the other muscles during draw-in exercise. Meanwhile, the EO activity (160.3±97.2 %MVC) was highest during trunk side flexion. There were significant interactions in the RA and EO during maximum pelvic anterior tilt. The activity of the RA and EO during maximum pelvic anterior tilt significantly increased after trunk side flexion (RA: pre-condition = 2.9±2.1 %MVC, post-condition = 4.1±2.6 %MVC, EO: pre-condition = 4.2±3.7 %MVC, post-condition = 5.6±4.1 %MVC). There was significant interaction in EO activity during maximum expiration, with the EO activity significantly increasing during maximum expiration after draw-in (EO; pre-condition = 13.8±4.0 %MVC, post-condition = 20.7±14.2 %MVC). Discussion It has been reported that increased shoulder superficial muscle activity change scapular kinematics in patients with frozen shoulder (Shih et al. 2017). Our results suggested that change in movement pattern of pelvic tilt increased in RA and EO activity after trunk side flexion. A previous study has reported that abdominal breathing produces higher EO activity than does normal breathing during standing (Park et al. 2015.) Additionally, the EO activity during expiration is considered to increase after draw-in exercise involved in abdominal breathing.

CONCLUSION The superficial trunk muscle exercise may change the muscle activity during pelvic anterior tilt.

PII.29 The effect of cooling at the elbow on Nerve Conduction Velocity and Motor Unit behavior: An exploration of a novel Neurological Assessment

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BACKGROUND AND AIM: Nerve Conduction Velocity (NCV) is a common assessment of demyelinating conditions, which is used in clinical practice. Slowing of conduction velocity is not believed to result in weakness, but may account for loss of deep tendon reflexes and is an important factor leading to neural transmission failure. It has previously been shown that a decrease in temperature of 1°C can cause a 2.4 m/sec reduction in nerve conduction velocity, however little is known on the neuromuscular effects, specifically the behavior of individual Motor Units (MUs). This study explored the effects of a standard therapeutic cooling using an ice pack at the elbow around a peripheral nerve, on the motor and sensory nerve conduction velocity and the behaviour of individual Motor Units.

METHODS: Eleven healthy individuals, aged 20 to 49, were tested using two non-invasive Nerve Conduction Studies (NCS); compound muscle action potentials of the First Dorsal Interosseous (FDI) muscle and sensory nerve action potentials, and a non-invasive investigation of the firing of MU using surface EMG decomposition (dEMG, Delsys Inc.) of FDI. dEMG is an innovative technology and method developed by De Luca et al. (2006) allowing a more detailed non-invasive investigation of the behavior of individual Motor Units, which has been shown to give a greater insight into neuromuscular control in individuals with different neurological conditions. Testing was performed prior to cooling, immediately after cooling and after 15 minutes of rewarming. Cooling was performed for 15 minutes using crushed ice and water to a skin temperature between 10-15°C, which is a standard method used in clinical practice.

RESULTS: Repeated measures ANOVAs with post hoc pairwise comparisons showed significant reductions in pulses per second (PPS) in the Motor Units firing between pre-cooling and post-cooling and between pre-cooling and re-warming ($p=0.013$, $p=0.045$) respectively, but no change between post-cooling and 15 minutes of re-warming. Similar patterns were seen in both the Motor and Sensory nerve conduction studies with significant differences between pre-cooling and post-cooling, pre-cooling and re-warming, and between post-cooling and 15 minutes of re-warming in the Sensory assessment ($p<0.01$), although the latter is of questionable clinical importance.

CONCLUSION: There appears to be a clear link between the sensory and motor NCS, and the mean MU firing rate recorded from dEMG. This data showed a 22% reduction in sensory and 26% reduction in motor nerve conduction delay causing a 12% reduction in mean MUs firing rate (Figure 1). This highlights the potential for dEMG as a novel neurological assessment technique, which could be used when NCV is difficult to measure and motor control is affected. This may be particularly important in early clinical stages before axonal degeneration is evident, which is still challenging for routine clinical neuro-physiological methods.

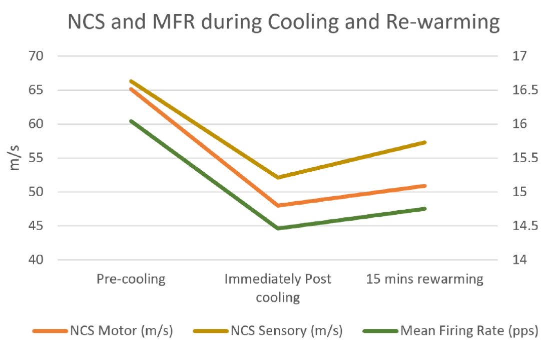

Figure 1. Behaviour of the motor and sensory NCS (m/s) and MFR (PPS) pre-cooling, immediately post cooling and 15 minutes of rewarming.

PII.30 Differences in force normalising procedures on estimates of relative output during submaximal eccentric contractions

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BACKGROUND AND AIM: Eccentric contractions (ECC) appear to require a unique activation strategy by the central nervous system, as evidenced by reduced electromyographic activity (EMG), motor evoked potentials and depressed H-reflexes compared to isometric (ISO) and concentric (CON) contractions at the same absolute load ([1]). However, due to greater intrinsic force generating capacity of muscle fibres during ECC, the understanding of neural modulation during submaximal ECC might be impeded by the force normalisation procedure used. This is particularly relevant when stimulating the nervous system to investigate neurophysiological responses because different normalisation procedures will inherently use different maximum force levels (e.g. CON vs ISO vs ECC) and hence will not be comparing like-for-like. This study aimed to assess the influence of different published normalising procedures, ISO maximum at intermediate muscle length (ISOi; [2]), contraction type specific maximum (CTS; [3]) and muscle length specific maximum (MLS; [4]), on the mean force and EMG activity during submaximal, anisometric contractions.

METHODS: Seven healthy, young males performed maximal ISO dorsiflexion at short (80 degrees), intermediate (90 degrees) and long (100 degrees) muscle lengths, and maximal CON and ECC contractions. Maximal values were used to construct a predictive model for representation of conceptual issues with different normalisation procedures. Thereafter, submaximal CON and ECC contractions were performed at 50% normalised to either ISOi, CTS or MLS.

RESULTS: Maximum ISO force increased with greater length (37.7 ± 7.7, 46.4 ± 6.3, 51.9 ± 4.3 Nm, respectively; $p < 0.05$), and CON (49.7 ± 5.7 Nm) was greater than ISO at short length ($p = 0.005$). ECC maximum (63.1 ± 8.3 Nm) was greater compared to any ISO or CON ($p < 0.005$). Maximum EMG activity did not differ across contraction types ($p = 0.306$). The predictive model showed that ISOi and MLS normalization should result in 13-14% smaller submaximal ECC force relative to CTS. Experimental data supported this, with CTS mean ECC force during submaximal contractions being greater compared to ISOi (11% difference; $p = 0.003$) and MLS (7% difference; $p = 0.018$). Similarly, EMG activity during submaximal ECC was greater for CTS compared to ISOi ($p = 0.021$) and MLS ($p = 0.025$).

CONCLUSIONS: These findings suggest that normalisation to ISOi or MLS are not accurate approaches for the assessment and prescription of submaximal ECC contractions, due to high discrepancy relative to ECC maximum. Therefore, the use of inappropriate force normalising procedures might have a substantial influence on the understanding of neural control during submaximal ECC contractions.

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PII.31 Stimulus-locked responses and corrective reaches are selective for low spatial frequency visual stimuli

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BACKGROUND AND AIM: To reach to a visible target, such as a coffee mug, visual information has to ultimately be transformed into motor commands. Normally, visual features about the colour, shape, and size of the mug are processed within numerous cortical areas, then relayed to the motor periphery via the corticospinal tract. However, in order to catch a falling mug, we must rapidly transform visual information into motor commands. These fast visuomotor transformations, and the neurological substrates that mediate them, are poorly understood. Recently, we have identified motor activity on upper limb muscles that we hypothesize is a signature of a fast visuomotor system. Stimulus-locked responses (SLRs) are bursts of muscle activity that arise time-locked within <100 ms of visual target onset, which have been observed on primate neck (Corneil et al., Neuron, 2004) and human upper limb muscles (Pruszynski et al., Eur J Neurosci., 2010). SLRs persist even if an eventual reach is withheld (Wood et al., Eur J Neurosci., 2015) or moves in the opposite direction (Gu et al., J. Neurosci., 2016). We have hypothesized that SLRs arise from a fast visuomotor system mediated by the tecto-reticulo-spinal pathway, which runs in parallel to the corticospinal pathway.

METHODS: We examined whether SLRs (experiment 1) and rapid on-line corrections (experiment 2) are preferentially evoked by Gabor patches composed of either high-spatial frequency (HSF) information selective for parvocellular visual pathways, or low-spatial frequency (LSF) information selective for magnocellular visual pathways (Merigan & Maunsell, Annu. Rev. Neurosci., 1993). All stimuli were perceptually-matched for contrast. In both experiments, we recorded upper limb muscle activity as participants seated in a robotic exoskeleton performed visually-guided reaches towards suddenly appearing Gabor patches presented either statically (experiment 1) or dynamically (experiment 2), where the target was jumped just after the arm started to move.

RESULTS: In experiment 1, LSF stimuli preferentially evoked shorter-latency (approximately 100 ms) and larger magnitude SLRs. SLR latencies increased systematically for Gabors composed of higher spatial frequencies. In experiment 2, the latency of online corrective movements also preferred LSF Gabors, and as seen in experiment 1, latency progressively increased for higher spatial frequency Gabors. Prevalence generally decreased with increasing spatial frequency. If detectable, HSF Gabors evoked responses approximately 100ms later than LSF Gabors in both experiments.

CONCLUSIONS: Our results are consistent with preferential visual input from the magnocellular visual pathway into the fast visuomotor system. Thus, when a premium is placed on response latency, only the necessary or available visual information drives both SLRs and quick on-line corrections.

PII.32 Evaluation of shoulder muscle coordination during arm elevation and lowering based on muscle synergy

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BACKGROUND AND AIM: Shoulder complex consists of the sternoclavicular, acromioclavicular, and glenohumeral joint. Many muscles around the shoulder complex need to work coordinately to accomplish a planned arm movement. Muscle synergy is a control module that operates muscles having similar functions as a unit, and is considered to be a feasible indicator representing muscle coordination. In this study, muscle synergy was extracted from the muscles in shoulder region. The purpose of this study was to investigate how the muscles in shoulder region were coordinated by the muscle synergy to perform arm elevation and lowering.

METHODS: Nine healthy men performed bilateral arm elevation and lowering at a rate of 60 rpm in sagittal plane. Muscle activities during the arm movement were measured in eight muscles (twelve portions) of the shoulder region using surface electromyography. Based on the non-negative matrix factorization, synergy activation coefficient and muscle weighting in the muscle synergy were extracted from the data matrix recorded muscle activities. The least number that provided 90% of variance accounted for was selected as the optimal number of synergy. To assess a variability of muscle synergy across the subjects, Pearson correlation coefficients were calculated.

RESULTS: Two muscle synergies were identified for all subjects with 95.9 ± 1.0% of variance accounted for during arm elevation and lowering based on the non-negative matrix factorization. With small variability across the subjects in both synergies ($r = 0.94 \pm 0.02$, $r = 0.85 \pm 0.08$ for synergy 1 and 2, respectively), synergies 1 and 2 had high synergy activation coefficients in the middle phase of elevation, and the early phase of elevation and latter phase of lowering respectively. On the other hand, synergies 1 and 2 respectively had similar muscle weighting to some extent with medium variability across the subjects ($r = 0.64 \pm 0.13$, $r = 0.60 \pm 0.22$ for synergy 1 and 2, respectively).

CONCLUSIONS: Two muscle synergies were extracted from the muscles of shoulder region and they activated in the different phase during arm elevation and lowering. In each synergy, the general muscle pattern existed through arm movement depending on the subjects. The findings suggested that arm elevation and lowering were performed by activating the muscles of shoulder region not as muscle-by-muscle but as units based on the two control modules having different functions.

PII.33 Acute effects of vibration exercise on human balance

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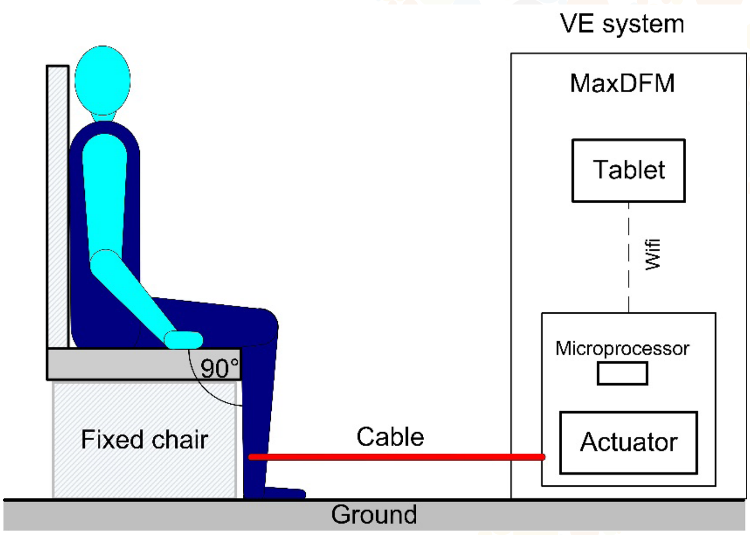
BACKGROUND AND AIM: Because of its enhanced neuromuscular stimulation, Vibration Exercise (VE) has been suggested to improve muscle strength and balance at lower training intensity. In particular, VE has been shown beneficial to produce long-term improvement of postural stability in the elderlies. However, the acute effects of VE on human balance are still unclear, and controversial results have been reported. With this study, we aimed at investigating these effects to clarify the underlying neuromuscular mechanisms elicited by VE. To this end, leg-curl muscle contractions were executed with and without VE, and balance measurements performed before and after each contraction task.

METHODS: Ten healthy volunteers (age = 25.7 ± 2.0) participated in this study. The study protocol prescribed one leg-curl (both legs) isometric contraction task from sitting position until failure. To this end, a frontal pulling force was applied to both ankles by a MaxDFM (HiPerMotion) dynamic pulley system. The legs were kept at 90 degrees and the pulling force was set at 50% of the maximum voluntary contraction. The tasks were executed with and without vibration on two different days. Vibration was produced with the MaxDFM system through 30-Hz modulation of the pulling force by 60% of its value. 30-Hz modulation is reported to induce the highest neuromuscular stimulation. Balance was measured before and after each task with a pressure distribution platform (Zebris Medical). To optimize reliability, the measurement protocol consisted of standing on the platform 3 times 60 s in a standardized position with closed eyes. The center of pressure was recorded over time and analyzed off-line for balance assessment by estimation of the mean velocity (MV), 95% confidence ellipse area, and standard deviation of the two stabilogram components (anterior-posterior and median-lateral). The balance difference before and after exercise was assessed by Wilcoxon signed rank test.

RESULTS: Only MV showed a significant difference (10% increase) with no vibration ($p = 0.03$). No statistical significance was obtained when vibration (force modulation) was superimposed.

DISCUSSION AND CONCLUSIONS: No substantial, acute effects were observed on balance, irrespective of the use of vibration. This might be due to the marginal contribution of the recruited muscles to balance. Only MV showed a significant increase without vibration, evidencing a balance decrease induced by fatigue. The same could not be observed with vibration. This might suggest the neuromuscular hyper-stimulation produced by VE to increase neural excitability, compensating for fatigue-induced balance loss. Further investigation with larger groups, also including different leg muscles, is required to elucidate on these interesting aspects.



PII.34 Dependence of EMG signals on body position in arm cycling movements

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BACKGROUND AND AIM: It is reported and commonly accepted that neural signals with higher amplitude have higher variances. We investigated whether this holds for EMG signals of individual muscles. We hypothesized that body position has a significant effect on the amplitude and on the variance (across time) of EMG signals.

METHODS: Arm cycling movements were performed on a custom made device (arm cycle ergometer) that can be used both in sitting (SIT) and supine (SUP) body positions. The participant grasped the handle of the device and rotated it with a cadence of 60 revolutions per minute unimanually separately by the dominant and non-dominant arm and also bimanually. The participants performed the movements in 2 sessions. In one of them they were in SIT position in the other one in SUP position. Muscle activities (surface EMGs) were recorded (900Hz) from the biceps, triceps, anterior delta and posterior delta muscles in both arms. EMG signals were filtered by a 4th order Butterworth band-pass filter. Frequencies below 25 Hz and above 300 Hz and frequencies 49-51 Hz were cut off. Then, root mean square (RMS, moving window 88ms) algorithm was applied to smooth filtered signals. Kernel probability density functions of the smoothed EMGs assessed in SIT and SUP were compared. Each arm's movement was represented in a 4 dimensional muscle space, each dimension corresponding to one muscle's EMG signal. The magnitude of the 4D muscle activity vector and its variance across time was computed.

RESULTS: We present results of 2 participants. Probability density functions show that for the dominant arm the mean of the biceps EMG signal is significantly higher in SIT compared to SUP position but its variance is not affected by body position. In the non-dominant arm both the mean and the variance of the biceps EMG is higher in SIT than in SUP. For the triceps both the mean and the variance is invariant to body position in the dominant arm but both of them are higher in SIT than in SUP in the non-dominant arm. The magnitude of the total muscle activity vector (in the 4D muscle space) increased but its variance did not increase in the dominant arm when SIT was compared to SUP positions.

CONCLUSIONS: Our examples suggest that higher individual muscle activities are not necessary associated with higher variances of muscle activities. Other muscle's activity may influence the relation between the mean and the variance of the signal. For some muscles whose mean EMG values increase the variance may also increase but for other ones not. The magnitude of the total muscle activity in the muscle space may increase while the total muscle activity variance does not. This was found in case studies for the dominant arm in arm cycling. The neural control of the dominant arm may be robust enough and in spite of the higher total muscle activity required in sitting body position, the control remains equally stable and it is reflected in the unchanged variance in muscle space. Measurements are planned for further statistical analysis. This work was supported by the GINOP 2.3.2-15-2016-00022 and EFOP-3.6.1-16-2016-00004

PII.35 The effect of muscle fatigue on neuromuscular activation of quadriceps femoris muscles during isometric sine-wave force tracking task

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BACKGROUND: It is known that muscle fatigue affects force steadiness or fluctuation during sustained isometric contraction (Contessa et al. 2009; Dundon et al. 2008). However, no attention has been paid for the effect of muscle fatigue on force accuracy and the neuromuscular activation strategy of quadriceps femoris (QF) muscle using rhythmic force matching task. PURPOSE: The purpose of this study was to clarify the effect of muscle fatigue on neuromuscular activation and force accuracy of QF during isometric sine-wave force exertion.

METHODS: Fifteen healthy men and women (25.1 ± 3.0 year) performed maximal voluntary contraction (MVC) of the knee extensors at a knee joint angle of 40° (full extension = 0°). Muscle fatiguing task consisted of 40 times intermittent MVCs (4s-extenstion and 2s-rest). Before and immediately after the muscle fatiguing task, the subjects performed force tracking task to match a given sine wave force signal on a computer monitor. This sine wave was expressed as a following formula: target = 4%MVC*sin (1/2πt) + 6%MVC, where t is time. Subjects performed 7.5 cycles (30 s); one cycle of sine wave was 4 s. One cycle of sine-wave force signal consisted of 6 phases (P1 to P6): P1 and P6 are ascending phases, P2 is a force switch phase from ascending to descending, P3 and P4 are descending phases, P5 is a force switch phase from descending to ascending. During the tasks, surface electromyogram (EMG) was recorded from vastus intermedius (VI), vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF). The root mean square (RMS) of EMG of each muscle was calculated in all phases and normalized by the RMS of the MVC. We investigated relative force error against the target as force accuracy. Median frequency (MF) of each muscle was calculated during muscle fatiguing task as index of muscle fatigue.

RESULTS: MVC was declined to 68.9% after muscle fatiguing task (453.4 ± 120.3 N to 312.3 ± 85.2 N, $p < 0.05$). MF of VI, VL and RF declined significantly and the rate of reduction of MF in RF (25.6%) was significant larger than that of other muscles (8.9-12.5%) ($p < 0.05$). Force accuracy was not significantly difference between before and after muscle fatiguing task. Normalized RMSs of vasti muscles increased after muscle fatiguing task in all phases ($p < 0.05$) (except for P4 and P5 for VM), whilst that of RF decreased in P4-P6 ($p < 0.05$). After muscle fatigue, normalized RMS of VI was larger than that of other muscles ($p < 0.05$).

CONCLUSION: The results suggest that muscle fatigue by intermittent 40 repetitions of MVCs do not affect on low intensity sine wave force control task. Normalized RMS was declined only for RF and MF of RF significantly decreased after muscle fatigue compared with other muscles. Thus, it is suggested that RF was affected by muscle fatigue more than other muscles. Furthermore, it is suggested that VI contributes for exertion force accurately by activating larger than other muscles after muscle fatigue.

PII.36 Position versus velocity controls in a simplified target acquisition task to improve future myoelectric controls

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INCIA - CNRS UMR 5287

BACKGROUND AND AIM. Most recent upper limb myoelectric prostheses use recorded muscle activities (EMGs) to control joint velocity rather than position. This choice is practical because 1) the prosthesis stops whenever muscles are relaxing, thereby requiring no sustained efforts to maintain a given configuration; 2) the temporal integration associated with this control minimizes the effects of noise that is inherent to EMG signals. However, velocity control is unnatural for at least two reasons 1) action execution must take into account relaxation time before stopping to the final position or planning movement corrections; 2) EMG control signals and their associated sensory information are no longer congruent at any moment with the actual prosthesis position. The present study was designed to assess the potential advantages and disadvantages of these two modes of control, using either isometric forces or noisier EMG as control signals in a simplified two-dimensional target acquisition task.

Methods: Twenty four participants reached for targets on a screen with cursor movements in a center-out task (8 directions, 3 target's distance, and 3 target's sizes). Cursor was controlled either with isometric wrist force (18 subjects) or with wrist muscles EMG (6 subjects), translated either in cursor position or velocity. Five gain values were tested for each control mode to modify the system sensitivity. A subjective usability questionnaire was added to detailed kinematics analysis to assess subjects' performances as well as preferences in the different conditions.

RESULTS. When controlled with isometric force, all subjects preferred the position control, and obtained better performance (trial duration 26.2% shorter and success rate 14.2% higher) than with the velocity control. Moreover, speed profiles obtained in velocity control mode showed markedly smaller speed peaks (49.7%) and longer corrective sub-movements (215.6%) than those observed in position control mode. Conversely, when the task was controlled with noisier EMG signals, all subjects preferred the velocity control, and obtained better performances (trial duration 9.3% shorter and success rate 50.4% higher) than with the velocity control.

CONCLUSIONS. Although the natural filtering property associated with temporal integration appears to critically favor the velocity mode of control when dealing with noisy EMG signals, this control mode is associated with substantially lower speed profiles and longer sub-movements than a position mode of control. This is likely due to the absence of moment to moment congruency between cursor position and motor commands as well as proprioceptive information, which forces participants to control their action solely based on vision. Future work will explore sensory substitutions as a way to reinstall the continuous sensorimotor congruency that is necessary for natural control.

PII.37 Effect of neuromuscular stimulation of antagonist muscles for voluntary drive

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BACKGROUND AND AIM: In rehabilitation for motor disturbances, one aim is to improve the control of motor function through motor training. This improvement is driven by use-dependent plasticity in motor performance. Training-based improvements in motor function are due to the effects of voluntary drive. Voluntary drive is an important central command that descends via the corticospinal tract in a volley to initiate muscle contraction; it is the brain activity seen during the phases of preparation, execution and modification in a muscle contraction. Motor training in healthy subjects has been found to positively affect motor learning and motor memory. Moreover, the significant factor in these effects may be various voluntary drives. Kaelin-Lang et al. (Kaelin-Lang, Sawaki, & Cohen, 2005) indicated that voluntary motor drive encodes motor memories in the primary motor cortex through active motor training.

METHODS: When electrical stimulation (ES) is applied to an antagonist or agonist muscle, it changes the primary motor cortex of the agonist muscle, and thus its voluntary drive, It is unknown whether the ES-derived cortical modification is more effective in facilitating contraction when applied to the agonist muscle, or if it is similarly effective when applied to the antagonist muscle. In this study, we compared the effects of weak and strong ES directed to the antagonist or agonist muscle during the premotor time in wrist extension, using a reaction time task. We recorded motor evoked potentials (MEPs) induced by transcranial magnetic stimulation (TMS) applied to the extensor carpi radialis (ECR; agonist) and flexor carpi radialis (FCR; antagonist), for both ES conditions.

RESULTS:In the ECR, when stronger ES intensities were applied to the antagonist, the MEP control ratio was significantly increased during the premotor time; furthermore, the MEP control ratio in the antagonist at the stronger ES intensity was significantly larger than that in the agonist for the same ES intensity. In the FCR, the MEP control ratio was also significantly greater at the strong ES intensity than at the weak ES intensity, and the MEP control ratio in the antagonist at the strong ES intensity was significantly larger than that in the agonist for the same ES intensity.

CONCLUSIONS: To conclude, involuntary antagonist muscle contraction due to ES induced an increase in voluntary drive in the agonist primary motor cortex. These results suggest that agonist corticomotor excitability might be enhanced by ES of the antagonist, which would in turn strongly activate the descending motor system in preparation of agonist contraction. Moreover, this concept might contribute to methods necessary for recovery of motor function in rehabilitation for neurological disorders (e.g. stroke) and muscle weakness in musculoskeletal disorders.

PII.38 Postural strategies for blind and sighted individuals during standing

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BACKGROUND AND AIM: Because vision is a powerful sensory input necessary to maintain good balance, this pilot study was conducted to investigate if sighted and blind people use different strategies (hip vs. ankle) to maintain balance in quiet standing.

METHODS: A total of 3 young adults (1 sighted, eyes closed, S1 and 2 congenitally blind, B1 and B2) participated in the study. Each subject stood (60 s / trial, 3 trials / condition) bipedally under the following 4 conditions: hard floor with neutral head position (baseline, HN), hard floor with neck extension (to reduce the input from the vestibular system, HE), soft floor (to reduce the input from the feet somatosensory system) with neutral head position (SN), and soft floor with neck extension (SE). The center of feet pressure (COP) was obtained via a force plate, while the head position, hip flexion/extension angle, trunk and leg segments angle (relative to the earth ground) were obtained using a 3 dimensional motion analysis system. The stability of the COP position, head position (both in the anterior-posterior direction) and the hip angle was calculated as root mean square (RMS) amplitude. In addition, the median frequencies of the COP was also calculated using fast Fourier transform. The amplitudes and median frequencies at HE, SN and SE were divided by those at HN.

RESULTS: Although both of the COP and head RMS amplitudes were lower for both B1 and B2 compared to that of S1 at baseline (HN), as the balance task became more challenging, the increase in the amplitudes was greater for B1 and B2 compared to that of S1 (1.82, 2 .84, and 4.73 for COP, and 1.72, 3.38 and 5.60 for head, both for S1, B1, and B2 at SE(/HN)). The hip angle RMS was similar at baseline across subjects, but those of S1 and B2 were lower (1.37 and 1.70 for S1 and B2, respectively) compared to that of B1 (3.16) at SE. The median frequency of COP at baseline was higher for B2 (0.17 Hz) compared to those of S1 and B1 (0.04 and 0.05 Hz for S1 and B1, respectively). The median frequency became lower at SE only for B2 (0.65). Moreover, the correlation coefficient of the trunk and leg segments angles at SE was higher for B2 (0.95) compared to those of S1 and B1 (0.77 and 0.51 for S1 and B1, respectively).

CONCLUSIONS: These data suggest that blind people can maintain balance comparable to that of sighted people with no vision by depending more on the remaining two sensory systems if the standing surface is stable. Although B1 and B2 are both congenitally blind, B2 depends more on the ankle strategy than on the hip strategy (the small hip angle RMS st SE), whereas vice versa for B1 (but unsuccessful use of hip strategy because both head position and hip angle RMS amplitudes are large), suggesting that young congenitally blind people do not have a uniform strategy to maintain balance.

MOTOR DISORDERS & NEURPHYSIOLOGY

PII.39 Influence of Parkinson's Disease in the Muscles of the Stomatognathic System

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BACKGROUND AND AIM: Parkinson's disease is a neurological disorder that promotes motor changes in the body. The objective of this study was to evaluate the electromyographic activity of temporal, masseter, and sternocleidomastoid muscles in individuals with Parkinson's disease.

METHODS: Twelve individuals with Parkinson's disease (PD - age mean 6.1±3.3 years) and twelve individuals without the disease (control group) (CG- age mean 65.8±3.0 years) participated in this study. The variable studied was: electromyographic activity in various postural conditions of the jaw (rest, protrusion, right and left laterality), captured by electromyograph with surface electrodes placed in temporal, masseter, and sternocleidomastoid muscles. The electromyographic normalized values were submitted to statistical analysis (SPSS, test t; $P < 0.05$).

RESULTS: The PD subjects showed greater electromyographic activity normalized compared to CG with statistically significant results for the right temporal and left temporal muscles, left masseter muscle and right sternocleidomastoid muscle in all clinical conditions assessed. Already the right masseter muscle and left sternocleidomastoid muscle only in clinical conditions of protrusion and right laterality (test t; $P < 0.05$).

CONCLUSION: The results of this study suggest that Parkinson's disease has a functional impact on the stomatognathic system. ACKNOWLEDGEMENT: FAPESP and CAPES

PII.40 The association between activity and stiffness of the back extensor muscles in people with low back pain

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BACKGROUND AND AIM: The flexion relaxation phenomenon (FRP) refers to relaxation of the extensor muscles at a specific point in trunk flexion when the lumbar spine hangs on the posterior ligaments and other passive structures. People with chronic non-specific low back pain (CNSLBP) often show heightened extensor muscle activity during trunk flexion and/or an absence of the FRP; however, this is not the case for all. Recent work has shown that people with CNSLBP demonstrate greater passive muscular stiffness of the erector spinae (ES). We therefore hypothesised that people with CNSLBP with greater passive and active stiffness of the ES would likely display an absence of the FRP or the greatest delay in the FRP. Thus, the aim of this study was to examine the associations between passive and active muscular stiffness of ES and multifidus measured with shear wave elastography (SWE), and the offset of ES activity during trunk flexion recorded with high-density electromyography (HDEMG).

METHODS: 14 participants with CNSLBP (7 men; age: 29.40 ±10.80 years) and 12 asymptomatic control participants (6 men; age: 26.47 ±5.47 years) were recruited. This study was approved by the University of Birmingham Ethics Committee. Participants with CNSLBP had a mean pain intensity of 2.2 ±1.6 on a numerical rating scale and perceived disability of 12.7 ±6.3% on the Oswestry Disability Index. With the participant positioned in prone, passive muscular stiffness of the ES and multifidus were measured (SWE LOGIQ S8 GE Healthcare, USA) bilaterally at the level of L3. Active muscular stiffness of ES was measured during active trunk extension, a position akin to the Ito test. For each muscle and side, the mean of 2 acquisitions (2x9 frames values) was calculated to obtain the shear modulus as a measure of muscular stiffness. HDEMG signals were detected with semi-disposable adhesive grids of electrodes (13x5) placed over the lumber ES bilaterally, positioned 2cm lateral to the L5 spinous process, following skin preparation. Participants performed 3 repetitions of full trunk flexion. The root mean square (RMS) value for each channel was calculated to generate an average RMS as an indicator of the amplitude of muscle activity during the full flexion phase and normalised to a 1s mean EMG amplitude in the standing position prior to each repetition. The offset of ES during trunk flexion was determined visually and the total activation time during trunk flexion calculated. Spearman's correlation coefficients were calculated to evaluate the association between measures of muscle activity and muscle stiffness.

RESULTS: The total activation time of ES during trunk flexion was comparable between groups (CNSLBP: 5.6 ±4.2s; controls: 2.3 ±1.0s, $p=0.106$) as was the mean normalised RMS during full trunk flexion (CNSLBP: 285.8 ±201.7%; controls: 222.0 ±194.1%, $p=0.297$). There was no correlation between the mean normalised RMS during full trunk flexion or total activation time of ES and muscular stiffness for the CNSLBP group. However, in the control subjects, higher active stiffness of the ES was associated with a delay in the myoelectrical silence ($r=0.64$, $p<0.05$).

CONCLUSIONS: In asymptomatic people, those with greater stiffness of the ES show a delay in the FRP. However, this association is absent in people with CNSLBP. These results provide additional evidence of alterations in neuromuscular function in people with CNSLBP which should be further explored in people with more severe symptoms and/or greater disability.

PII.41 Effect of Intermittent Hypoxia on Upper Extremity Function in Individuals with Spinal Cord Injury

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Shirley Ryan AbilityLab

BACKGROUND AND AIM: Spinal cord injuries (SCI) disrupt the pathways between brain and spinal cord, resulting in impairment of motor control and loss of independent mobility. Most SCIs are incomplete, however spontaneous plasticity, mediated via the spared spinal pathways is slow and often insufficient to restore lost function. One unique approach to augment plasticity in spinal networks is via intermittent brief exposure to mild hypoxia i.e. brief bouts of low oxygen in the inspired air (also known as acute intermittent hypoxia or AIH). This protocol has been demonstrated to increase voluntary force generation at the ankle joint as well as improve locomotor function in persons with SCI. Whether AIH induced neuroplasticity is equally prevalent in spinal motor pathways regulating upper limb musculature is not known. Accordingly, we tested the hypothesis that AIH will augment upper limb neuromotor function in individuals with incomplete SCI.

METHODS: A randomized, blinded, placebo-controlled and crossover study design was used. We measured isometric elbow flexion and extension strength during maximal voluntary contraction (MVC) in 10 individuals with chronic, incomplete cervical SCI before and 60 minutes after a single session of AIH (15, 90-second episodes of 10% oxygen). RESULTS were compared with trials when subjects received sham hypoxia (15, 90-second episodes of 21% oxygen). Electromyographic activity was also recorded from the biceps brachii and triceps brachii muscles using a 128 channel high density grid during elbow flexion/extension tasks. The root mean square (RMS) value for each channel was calculated to generate RMS muscle activity maps.

RESULTS: We found that force output during isometric MVC at the elbow flexion and extension increased by 43 ± 13% and 51 ± 22%, respectively, following AIH. In contrast, force output during flexion and extension changed by 13 ± 8% and -4 ± 7% following sham AIH intervention. The change in strength correlated with increased activation of biceps brachii and triceps brachii. Global average RMS values from biceps and triceps muscles increased by 32.5 ± 23% and 27 ± 8% following AIH, and by 6 ± 11%, and -3 ± 10% following sham AIH, respectively.

CONCLUSIONS: These results show that intermittent hypoxia can potentially be used to induce spinal plasticity and enhance force output in individuals with incomplete SCI. Future studies will focus on the impact of intermittent hypoxia on sub maximal levels of contraction in individuals with SCI.

PII.42 Impact of Osteoarthrosis in the Muscles of the Stomatognathic System

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BACKGROUND AND AIM: This research analyzed the electromyographic activity in the postural clinical conditions of the jaw in subjects with osteoarthrosis diagnosis.

METHODS: Participated 28 individuals aged between 40 and 70 years, both genders, distributed in two groups: with osteoarthrosis (n=14, mean ± SD 50.4 ± 2.0 years) and control (n=14, mean ± SD 50.3± 2.2 years). This research was approved by the Research Ethics Committee of Ribeirão Preto Dental School, University of São Paulo, Brazil. Right masseter (RM), left masseter (LM), right temporal (RT) and left temporal (LT) muscles were evaluated with an electromyograph Delsys Trigno TM wireless, analyzing the electromyographic static conditions in rest, protrusion, right laterality and left laterality. The electromyographic normalized data were submitted to statistical analysis (SPSS, test t; $P < 0.05$).

RESULTS: There was an increase of electromyographic activity for both sides of masseter and temporal muscles in the rest clinical condition. An increase of electromyographic activity was also observed for left masseter and left temporal muscles in protrusion, for left masseter and left temporal muscles in the clinical condition of right laterality and for left masseter muscle for the clinical condition of left laterality. The results were not statistically significant (test t $P < 0.05$).

CONCLUSION: The results of this research demonstrated a hyperactivity of all muscles evaluated in the clinical condition of rest and functional alterations of the stomatognathic system related to laterality and protrusion conditions.

ACKNOWLEDGEMENT: FAPESP, CAPES and CNPq.

PII.43 Changes in function due to high intensity exercise in Parkinson's Disease examined using instrumented clinical tests

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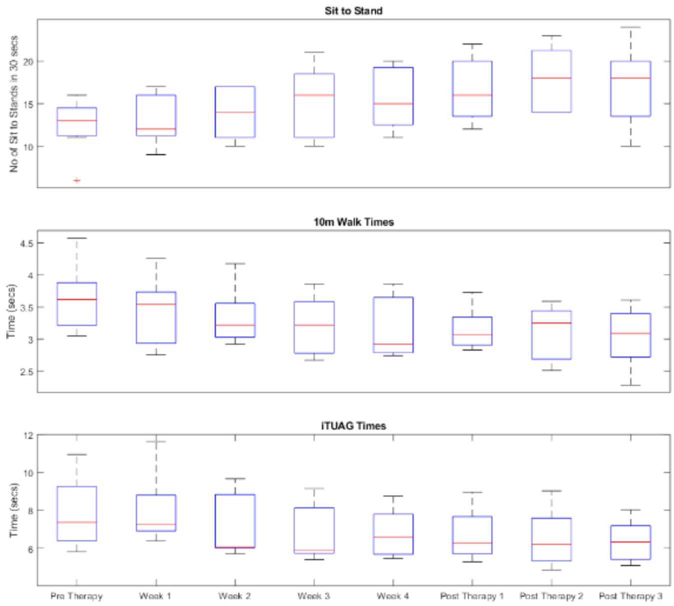
BACKGROUND AND AIM: High intensity exercise interventions involving large amplitude movements have shown benefits in the treatment of bradykinetic and dyskinetic Parkinson's patients. LSVT BIG®, a derivative of LSVT LOUD®, focusses on increasing the amplitude of movements during high intensity exercise sessions. The treatment consists of 16 one hour sessions over a four week period and to date has shown clinical improvements in UPDRS and clinical scores with respect to other exercise therapies such as Nordic walking. To determine whether the clinical improvements observed following LSVT BIG® therapy are reflected in instrumented measures, EMG and accelerometer data were recorded from patients undergoing LSVT BIG® therapy during standard clinical tests including 30 second sit to stand, 10m walk and instrumented timed-up and go (iTUG).

METHODS: EMG (1925.93Hz) and tri-axial accelerometer (148.1Hz) data were recorded using wireless surface electrodes (Trigno® Delsys Inc., Natick, MA, USA) from a group of older adults with Parkinson's disease (n=7, age = 74.28 yrs ± 6.89) and a group of healthy age matched volunteers (n = 7, age = 68.71 yrs ± 3.15). Sensors were placed on the surface of the skin over the rectus femoris, vastus medialis, vastus lateralis, tibialis anterior, gastrocnemius lateralis, biceps femoris and semitendinosus muscles using SENIAM guidelines. An accelerometer was placed over the fifth lumbar vertebrae (L5). Recording sessions for the PD group took place 2 weeks pre-therapy, once per week for the four weeks of therapy and 2, 5 and 13 weeks post therapy. The data for the control group were recorded using the same clinical tests during a single session. UPDRS scores were calculated on the first and last day of therapy and the final post-therapy recording session. Changes in clinical scores over the course of the therapy were analysed using a one-way repeated measures ANOVA. The Wilcoxon-Mann-Whitney test was performed to compare the differences in the clinical scores between the control and PD groups at the start and end of therapy.

RESULTS: Significant improvements were observed in the patient group in the number of sit to stands completed in 30 seconds, the time to complete a 10m walk, the time to complete an instrumented timed up and go test and in the UPDRS scores ($p < 0.05$ for all) over the course of the therapy (see Figure 1). Pre-therapy sit to stand counts showed a significant difference between the Parkinson's patients and the control group ($p < 0.05$) however, the sit to stand counts post-therapy compared to the control group were not significantly different ($p > 0.05$).

CONCLUSIONS: The use of standard clinical tests to assess changes in function due to LSVT BIG® therapy reveal significant improvements. Further analysis of the outcomes of this therapy using EMG and accelerometry is in progress.
Figure 1: Boxplots showing the respective increase and decrease in the clinical scores over the course of therapy. ANOVA revealed a significant increase in 1 ($p < 0.01$), decrease in 2 ($p < 0.01$) and decrease in 3 ($p < 0.01$).


Sit to Stand
No of Sit to Stands in 30 secs
10m Walk Times
Time (secs)
iTUAG Times
Time (secs)
Pre Therapy
Week 1
Week 2
Week 3
Week 4
Post Therapy 1
Post Therapy 2
Post Therapy 3

PII.44 Audiovisual Multisensory Processing and evoked potentials in Adult Attention-Deficit/Hyperactivity Disorder

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BACKGROUND: Multisensory integration (MSI) is a fundamental form of sensory processing, involving the integration of multiple simultaneous sensory stimuli originating from more than one modality, which frequently occurs in most day-to-day tasks. The level of success in which MSI occurs may have a profound influence on how individuals perceive and therefore interact with the environment. Audiovisual (AV) MSI commonly occurs during many common activities of daily living. Attention-deficit/hyperactivity disorder (ADHD) is a common developmental disorder affecting approximately 2-4% of the general population. Individuals with ADHD have prominent cortical structural changes but it is unknown whether the cortical changes alter MSI functionality.

METHODS: 11 control and 5 participants with ADHD (age of physician diagnosis 13.2 ±5.26 years) participated. The Adult ADHD Self-Report Scale (ASRS-v1.1), handedness, and neurological screening questions were administered. A simple AV response time (RT) task was programmed using E-Prime 2.0 to measure MSI. Participants were instructed to respond to an auditory (60ms), visual (60ms), or AV stimulus representative of the colour red. 8 blocks of 102 trials were completed. The same button was used to respond to all three stimulus conditions, resulting in a truly RT dependant task. 64-electrode electroencephalography (EEG) collected evoked potentials (EPs) for each stimulus type. Peak-to-peak amplitude and RT for each stimulus were analyzed.

RESULTS: The ADHD group had a significantly enhanced RT vs controls to auditory (297.60ms ± 9.19 vs. 314.66 ms ± 19.13, p=0.041); and multisensory (221.54 ms ± 12.28 vs. 242.91 ± 15.03; p=0.026) stimuli while the visual RT approached significance (228.63 ms ± 15.44 vs. 249.75 ms ± 18.01; p=0.066). Early MSI EP's for the ADHD group had significantly smaller amplitudes vs controls (1.15µV ± 1.32 vs. 2.92µV ± 1.11 for controls, p=0.04) for the 100-120 ms latency. MSI EP's between 180-210 ms showed a similar trend (ADHD mean = 2.74µV ± 0.53 vs. Control mean = 3.75µV ± 1.84; p=0.09).

DISCUSSION: These results are the first to look into both neurological and behavioural MSI differences in young adults diagnosed with ADHD. The ADHD group had enhanced RT to auditory, visual and MSI stimuli compared to controls, while also having decreased peak-to-peak MSI EP amplitudes, suggesting a lack of integration despite fast response times. Additional ADHD participants need to be collected to confirm these results. This study used a simple RT task, future studies need to discern whether differences are present when participants are asked to respond accurately to a stimulus, for example during a two-alternative forced-choice discrimination task (i.e. choose correctly between a red or blue stimulus). These results then need to be correlated to the MSI, auditory and visual EP changes.

PII.45 Long-term changes in the impedance at the electrode-tissue interface of deep brain stimulation electrodes

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BACKGROUND AND AIM: Electrodes, implanted in the brain either for stimulation or recording, offer the potential for significant therapeutic and rehabilitation interventions across a range of applications including deep brain stimulation, brain machine interfaces and neural control of prostheses. Using different target structures, deep brain stimulation is an established treatment in Parkinson's disease and other movement disorders including dystonia and essential tremor, and is being explored for a wide range of conditions such as epilepsy, Tourette's syndrome, obsessive compulsive disorder (OCD) and depression. The efficacy of all these implantable stimulation and recording systems degrades over time due to changes at the electrode-tissue interface, but this area is not well studied. It is known that long-term implantation causes changes in the impedance of the surrounding tissue due to the formation of a glial scar, but the exact electrical and mechanical properties of the tissue formed, and its effect on the recording or stimulation ability of the electrodes is not fully established. Furthermore, the influence of active electrical stimulation on this mechanism is unknown.

METHODS: The aim of this study is to investigate the changes in impedance around implanted electrodes in rats. All animal experiments have been approved by the UCD Animal Ethics Committee and licenced by the Health Products Regulatory Authority of Ireland. Bipolar concentric electrodes are implanted in the subthalamic nucleus region of the brain of adult male Wistar rats weighing 350-450g at the time of surgery. The rats are followed for 8 weeks where half of the rats receive stimulation via the electrode (130 Hz, 60 ms duration biphasic rectangular pulses, with an amplitude below the threshold for turning movements) and half of the rats to not receive stimulation. Stimulation is applied via wireless programmable headstage which is inductively charged and able to deliver 24/7 stimulation. The electrical impedance of the electrode tissue interface is monitored using impedance spectroscopy.

RESULTS: In the inactive electrodes, the electrical impedance at the electrode tissue interface was reduced in the first days after implantation, but increased markedly after 3 days and then remained stable over the next 7 weeks.

CONCLUSIONS: Experiments involving the active electrodes are still ongoing and differences between active stimulation electrodes and electrodes without stimulation will be presented.

PII.46 Why don't we bite our tongue while eating? An intramuscular electromyography study to elucidate the neuroanatomical circuitry between the masseter and the genioglossus in humans during chewing

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BACKGROUND AND AIM: Feeding is a complex motor activity that depends on the coordination of more than 26 pairs of muscles and five cranial nerves. Studies conducted in animal models and humans have concluded that some degree of unconscious coordination exists between the jaw and tongue during mastication. Such coordination is clearly important for preventing damage to the tongue. The purpose of this research was to study tongue-jaw coordination during fictive chewing in healthy humans and to evaluate the presence of inhibitory interneurons within the circuitry that enables this coordination.

METHODS: Ten college-aged subjects have so far participated in this ongoing study. Fine-wire multiunit bipolar electrodes were inserted percutaneously into the masseter and perorally into the genioglossus. While recording from these two muscles, subjects were instructed to chew on a plastic mouth guard that had been fitted to their lower teeth. In addition, electrical stimulation was delivered to the lip while subjects activated the two muscles to produce single or multiunit activity. For analysis of the data obtained during chewing, the EMG records were high-pass filtered and rectified, after which waveform averaging was done relative to trigger marks placed at the onset of masseter activity. Multiunit activity during electrical stimuli delivery was analyzed by rectifying the EMG records, averaging the waveforms relative to the electrical stimuli and applying the cumulative sum (CUSUM) method of analysis. A significant inhibition event was defined as a downward deflection having an amplitude greater than that of the error box.

RESULTS: Qualitative evaluation of the average waveforms during chewing revealed a temporally antiphase relationship between the masseter and genioglossus in four subjects. In two additional subjects, activation of the masseter slightly preceded that of the genioglossus. In cases where electrical stimuli 5-7 times the threshold stimulus for perception was delivered to the lip during multiunit activation (n=6 subjects), significant inhibition in the masseter was evident early on in five subjects (latency: 16.29 ± 2.41 ms; duration: 13.31 ± 1.92 ms, range of amplitude: 1.59-14.62 mV). 1/6 subjects had a prominent single inhibition in the masseter occurring relatively later at 43.77 ± 3.36 ms and having a duration of 46.7 ± 6.58 ms. In 3/5 of the subjects with the early masseter inhibition, a secondary inhibition in the masseter was observed (latency: 50.49 ± 7.44 ms; duration: 18.82 ± 10.73 ms; range of amplitude: 4.33-28.12 mV). Significant lingual inhibition was detected in 5/6 of the subjects (latency: 46.87 ± 8.66 ms; duration: 25.07 ± 16.33 ms; range of amplitude: 0.702-17.32 ms).

CONCLUSION: The preliminary results of our study suggest a circuitry between the genioglossus and the masseter in which shared inhibitory interneurons achieve antiphase or near-antiphase activation of the two muscles during chewing.

PII.47 Ageing. It's a Trap! Neuromuscular properties of the superior trapezius.

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The superior trapezius (ST) muscle has both cranial (CN XI) and spinal nerve motor innervation in humans. The ST acts to elevate and stabilize the scapula during arm and neck movements. With adult ageing of the neuromuscular system, there has been limited investigation of muscles with cranial motor supply, in the masseter (CN V) and laryngeal muscles (CN X) there is a shift to a predominant type II fibre distribution which is counter to findings reported for limb muscles. The ST is the only proximal muscle with partial cranial innervation that has been assessed using Decomposition-based Quantitative Electromyography (DQEMG) in health and disease. Due to the unique aspects of the ST, we hypothesized that the ageing process will be attenuated, and we will observe electrophysiological evidence associated with a type II fiber motor unit (MU) distribution in aged when compared with young. During 3-4 visits to the neuromuscular lab, ten young (26 ± 4 y) and ten old (81 ± 4 y) men participated in this investigation. In a modified Nautilus neck and shoulder dynamometer, voluntary isometric force was recorded during bilateral scapular elevation with visual force feedback provided. To assess MU discharge rates (MUDR), tungsten microelectrodes were inserted into the left portion of the ST during voluntary contractions at maximal and submaximal intensities. Supramaximal stimulation of the accessory nerve was used to generate a maximal compound muscle action potential (CMAP) and DQEMG was used to obtain a MU number estimate (MUNE), and to assess needle detected and surface MU potentials (MUPs and sMUPs). The old group achieved ~50% of the maximal voluntary isometric force of the young. MUDRs were lower by 40-50% at submaximal to maximal voluntary isometric contraction intensities in the old compared with the young. CMAP amplitude was less by 40% along with reduced sMUP parameters in the old resulting in no significant difference in MUNE between young (228 ± 121) and old (209 ± 85). In the old, sMUPs had lower negative peak amplitude (53.3 ± 15.6 µV) and area (361.3 ± 99.6 µVms) as compared to young (71.1 ± 26.5 µV; 427.7 ± 157.4 µVms). Furthermore, MUPs of the old also had greater complexity with increased duration and number of turns compared to the young. Despite the expected age-related muscle weakness and lower CMAP responses, the estimated numbers of MUs in the ST were not lower in the old men. Thus, these age-related results are at variance with several reports from many proximal and distal limb muscles and may indicate that muscles with cranial innervation are affected differently during ageing. These findings suggest that the ST MUs in aged men may not have undergone or may be past the process of compensatory remodeling, and that age-related reductions in muscle fibre number and/or size may be responsible for the reduced CMAP and sMUP observations.
Supported by NSERC.

MOTOR PERFORMANCE & SPORTS SCIENCE

PII.48 Effect of resistance training on motor unit firing pattern in elderly

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Introduction: It is well known that resistance training improves muscle strength not only in young but also in elderly. While adaptations in muscular system such as muscle hypertrophy had been investigated in many studies, adaptations in neural system have not been fully understood. We aimed to investigate the effect of resistance training on motor unit firing pattern in elderly.

Methods: Twenty-five male and female elderly participated in this study. The subjects were randomly assigned to either training (TR) group and control (CN) group. For the subjects in TR, resistance training was carried out two times a week with each session consisting of three sets of ten bilateral horizontal leg presses at 70% of 1 repetition maximum for 6 weeks. Maximal voluntary contraction (MVC) and submaximal ramp contractions from 0 to 70% of MVC during isometric knee extension were tested at the first day of intervention (0W), and at 3 (3W) and 6 weeks (6W) after beginning of the intervention study. Surface EMG signals of the vastus lateralis muscle were recorded with a semi-disposable adhesive grid of 64 electrodes and were decomposed with the Convolution Kernel Compensation (CKC) technique into individual motor units. Detected motor units were separated into three groups by recruitment threshold, i.e., < 20% of MVC, 20~40% of MVC, and 40~60% of MVC, and compared among three periods in each group at same absolute force levels.

RESULTS: There were no significant differences in MVC force between TR and CN at all periods ($p > 0.05$) and no significant effects of intervention for TR and CN ($p > 0.05$). In CN group, no significant differences in firing rate for all the investigated motor unit groups were found at any period ($p > 0.05$). In TR group, firing rates of motor units recruited at ~20% of MVC were significantly greater for 3W and 6W than those at 0W, but only at 40 and 50% of MVC ($p < 0.05$). Motor units recruited at 20~40% and 40~60% of MVC demonstrated no significant difference in firing rate among the periods ($p > 0.05$).

Discussion: We found an increase of firing rate in the motor units recruited at ~20% of MVC by resistance training intervention, but not in the motor units recruited at 20~40% and 40~40% of MVC. This finding suggests that neural adaptation following resistance training is selectively occurred in low-threshold motor units in aged populations.

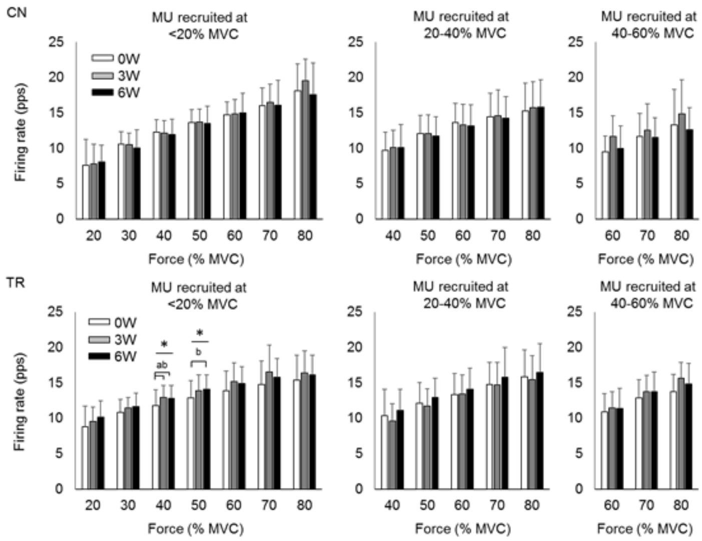

Fig 1. Mean firing rate of motor units that recruited at ~20% of MVC (Left), 20~40% of MVC (Center), and 40~60% of MVC (Right) for the subject group with (TR) and without (CN) resistance training. * significant effect of intervention, [a] significant difference between 0W and 3W, [b] significant difference between 0W and 6W

PII.49 0Investigation of parasympathetic nervous system response with measuring R-R interval of pulse using wrist-watch during different jogging

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BACKGROUND AND AIM: Daily, routine, aerobic exercise is recommended for health promotion and the prevention of disability. A pulse measuring wrist-watch was recently developed as a practical, attractive, and simple tool for physical and mental health management and performance improvement. The purpose of this study was to investigate which conditions during jogging were less stressful by measuring the R-R interval (RRI) of the subject's pulse using a wearable wrist-watch (Wearable GPS-SF850, Epson Japan).

METHODS: Nineteen healthy, college-going, male students ran at a speed of 7.5 km/h for 16 minutes over a two kilometer distance under the following five conditions: on the flat outside road (O), O while listening to their favorite music, O with a pacemaker, O with their favorite music and a pacemaker, and on the treadmill inside. The temperature inside and outside were made equivalent. Subjects were asked to read the research information sheets and sign the consent form prior to their participation. The Borg scale for intensity after jogging was set between 11 (fairly light) and 13 (somewhat hard). The order of the five jogging conditions was randomized, and a one-week break was taken between conditions for rest. Before jogging, the subjects rested for three minutes by sitting in a chair. The pulse data from the watch was calculated by dividing by sixty, then the Poincare plot method was applied as figuring dots in number (k) RRI in X axis and number (k 1) RRI in Y axis continuously. A rectangular plot covering all dots was drawn on a seat and the ratio of the minor diameter (S) and the major diameter (L) was determined for each jogging condition. The values of S/L, a considerable index of parasympathetic nerve stress level under each condition, and a mean value and variation were subjected to a significance test using one-way analysis of variance and the F-test, with the α level set at 0.05.

RESULTS: There was no difference in the mean S/L values between jogging conditions. The variance of S/L during the condition of jogging with music combined with the pacemaker was significantly greater than that on jogging on the flat road (Figure 1). Generally, the value of S/L decreases as the parasympathetic nerve dominant status in the body is reached. It increases when we feel stress and tension in our mind. The results suggest that the individual difference in autonomic nerve response could occur when young male individuals listen to music and jog with a pacemaker.

CONCLUSIONS: It was difficult to apply exactly the same intensity load to the subjects, as exercise tolerance varies among individuals. Further study is needed to investigate reliable and less stressful interventions during jogging.

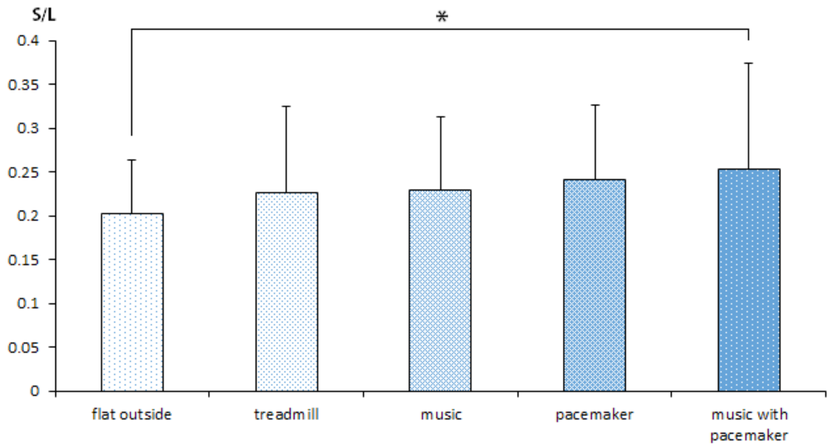

Figure 1. S/L during different conditions of jogging. *: p <.05

PII.50 Muscle fatigue and metabolic responses during whole-body electrical myostimulation with and without voluntary exercise

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BACKGROUND AND AIM: Although the effect of electrical myostimulation (EMS) on the muscle fatigue and metabolic responses of the human body has been reported in many studies, the effects of its combination with voluntary exercise and/or inter-individual differences in age and body composition are not fully understood. The present study investigated the effects of combining EMS and voluntary exercise on metabolic responses in humans with various ages and body-composition profiles.

METHODS: Thirteen males, ranging in age from 24 to 60 years old and whole-body fat from 14.8 to 30.7%, participated in the present study. In the EMS trial, EMS was applied to the quadriceps, hamstrings, gluteus, abdominal, back, and upper arm muscles via wet-cloth electrodes at 20 Hz for 15 min. In the EMS with additional voluntary exercise (EV) trial, the subjects performed whole-body light aerobic dance with the same EMS applied in the EMS trial. The stimulation intensity of EMS was the highest intensity possible that still allowed the subjects to perform whole-body light aerobic dance. The two trials were conducted on different days and in random order. Before and after the trials, the maximal voluntary contraction (MVC) force during isometric knee extension and blood lactate concentration were measured.

RESULTS: The MVC force significantly decreased after both EMS (-14.2%) and EV (-17.1%) compared with before the trials ($p < 0.05$), with no significant differences in MVC noted between EMS and EV trials after trial completion ($p > 0.05$). The blood lactate concentration significantly increased from 1.3±0.4 to 3.2 ±1.2 mmol/L after EMS and from 1.3±0.4 to 4.8±2.6 mmol/L after EV, with the concentration in EV being significantly higher than that in EMS after trial completion ($p < 0.05$). There were significant negative correlations between whole-body fat/subcutaneous tissue thickness at the abdomen and the blood lactate concentration after EV ($p < 0.05$) and after this relationship was also seen after EMS ($p < 0.1$).

CONCLUSIONS: Our findings suggest that additional voluntary exercise during whole-body EMS can induce a more marked metabolic response, and its effect is partly influenced by inter-individual differences in body composition profiles.

PII.53 Muscle activity and steering performance using five steering input devices operating a heavy machine simulator

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Introduction: Work related upper body musculoskeletal symptoms and disorders constitute a major problem for heavy machine operators. Steering input devices mediate risk factors of upper body musculoskeletal disorders, i.e. muscle load. Only few studies have compared commercially available steering input devices in terms of imposed muscle load. Five common steering input devices (conventional steering wheel, fast steering wheel, mini steering wheel, first-order joystick and second-order joystick) were evaluated in terms of muscle activity and steering performance during heavy machine simulator driving.

METHODS: Fifteen healthy right-handed novice males completed five laps on a simulated track with each steering input device. Muscle activity was measured from eight muscles (flexor carpi radialis, extensor carpi ulnaris, biceps brachii, triceps bracii, anterior deltoid, posterior deltoid, clavicular part of pectoralis major and upper trapezius) on the left side controlling the steering input devices. Steering performance was quantified as completion time, angular deviation from the reference path of the track and steering reversal rates. Participants subjectively ranked steering input devices.

RESULTS: The mini steering wheel and joysticks showed lower muscle activity compared to the conventional and fast steering wheel. The conventional steering wheel showed slowest completion time and was subjectively ranked worst while the first-order joystick was ranked best. The three steering wheels showed lower angular deviation compared to the second-order joystick. Highest steering reversal rate was found for the first-order joystick. Discussion: Lower muscle activity in the mini steering wheel and joysticks was likely due to differences in range and velocity of movements, as the conventional and fast steering wheel required participants to move in a wider range and faster. Despite a lower steering ratio for the fast steering wheel, no difference in muscle activity was found as compared to the conventional steering wheel. This can likely be explained by slower steering movements during the use of the conventional steering wheel. The first-order joystick was possibly ranked best because it entailed less muscle load and was more intuitive to use. The higher angular deviation for the second-order joystick can be attributed to it being more difficult to control. The higher steering reversal rate for the first-order joystick potentially indicates a more erratic steering and higher cognitive demand.

CONCLUSION: Results suggest that the mini steering wheel and joysticks reduce muscle load, while not comprising steering performance extensively. However, for all evaluated steering input devices, muscle load exceeded the recommended threshold. This displays a prevailing need for developing steering input devices that reduce risk factors of upper body musculoskeletal symptoms and disorders without compromising productivity.

PII.54 Relationship between trunk kinematics measured by smartphone inertial sensor and contact mat scores in plyometric tests

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OBJECTIVES: to describe and analyse the acceleration variables in a plyometric jump test in different heights using the inertial sensor built into a smartphone iPhone 4S® and the jump contact mat.

METHODS: A cross-sectional study was conducted involving sixteen healthy young adults (mean age ± SD: 25,59 ± 4,14 years, body mass index: 24,19 ± 3,08 kg/m2). Flight time, contact time and jump height in Drop Jump test from 60 (DJ60) and from 30 centimetres (DJ30) were measured using a contact mat and linear acceleration was recorded during the test using the iphone 4S® inertial sensor.

RESULTS: The greater acceleration values were localised in DJ60, as happened in the contact mat variables. Multiple regression analysis was performed for each DJ test: jump height was used how to dependent variable and the most relevant variables how to predictor variables (weight and maximum angular velocity in Y axis for DJ60 and weight and maximum acceleration in Z axis for DJ30 analysis). We have found a significant regression model for the DJ60 jump test ($R2 = 0.515$, $p<0.001$) and a for the DJ30 jump test ($R2 = 0.460$, $p<0.01$).

CONCLUSIONS: According to the results obtained in this study, the built-in iPhone 4S® inertial sensor is able to measure acceleration for healthy young adults performing a vertical jump test DJ. The acceleration kinematics variables are higher in the DJ test from 60 cm than from 30 cm.

PII.55 Leg and trunk muscle activity in different positions performing on a double slackline in young adults

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BACKGROUND AND AIM: Balance performance is a core ability to meet the challenges in daily life and participating in many sports. The benefit of higher balance performance can lead to a better postural control resulting in less falls, higher performance in sports accompanied by less injuries, e.g. in the lower limbs. Better postural control is also supposed to be responsible to decrease the occurrence of back pain. To improve balance performance a variety of approaches on stable and unstable surfaces are described. A rather unnoticed training device is the double slackline, even it is a safe and challenging device that can be used in sports and therapy independent of age and level of fitness. As there is a wide area of application we were interested how muscle activity remains in leg and trunk muscles on a fixed and moving double slackline in variety of common postures.

METHODS: Nineteen young and healthy adults (9 female; age 25.2 (SD2.5) y; body mass 59.1 (3.5) kg; height 1.67 (0.04) m; 10 male; age 26.8 (2.7) y; body mass 77.8 (8.1) kg; height 1.78 (0.06)) volunteered in this cross-sectional study. In six different static positions (e.g. upright standing, squat (100°), quadruped position knees off the floor) we explored muscle activity (ProEMG, myon AG, Schwarzenberg, Switzerland) of twelve leg and trunk muscles (tibialis anterior, soleus, vastus medialis, biceps femoris, internal oblique and erector spinae on both body sides). The six different positions had to be performed on two types of double slacklines in randomized order. The differences between a static (e.g. slackstar) and moving slackline (e.g. haramed) is apparent because the moving one possesses only to fixing points for the line, while it is redirected on one end. In contrast, the static is build out of two separate lines fixed at both ends. Muscle activity during standing on the floor in the six positions were used as a normalization and data collected over five seconds in each task and condition and processed for further analysis.

RESULTS: No differences in muscle activity between the two types of slacklines could be found. However, muscle activity in the body postures on the slacklines were significantly higher compared to normalization task on the floor (firm base) especially in squat position (15°) in vastus lateralis ($p>0.01$), squat position (100°) in soleus ($p>0.01$) and in quadruped position in internal oblique ($p>0.01$).

CONCLUSIONS: Our study reveals that there are no differences in muscle activity comparing a fixed to a moving double slackline in a variety of body postures. Since in this study no type of double slackline produced higher muscle activation, so far there can be drawn no conclusion which should be used preferably. Further studies should add body movement in order to better emphasize the differences in construction between the two slacklines. Donath, L., Roth, R., Zahner, L., & Faude, O. (2017). Slackline training (Balancing Over Narrow Nylon Ribbons) and balance performance: a meta-analytical review. Sports Medicine, 47(6), 1075-1086. Words: 488 Characters: 3073 (including spaces)

PII.56 Evaluating Aberrant Muscle Activity Patterns During Functional Tests

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Background: It is often the case that EMG data collected during the performance of functional tests is evaluated via visual inspection of the EMG recordings to detect aberrant muscle activity patterns. The severity of aberrant behaviors is typically captured using an ordinal scale. In this study, we developed a novel approach based on regression models of EMG data features to derive quantitative measures of the severity of aberrant muscle activity patterns.

METHODS: EMG data was collected from 62 subjects during the performance of functional tests consisting of batteries of static and dynamic tasks. Data recorded during the performance of static tasks was visually inspected by a field expert to assess the severity of muscle spasms and abnormal levels of muscle activity at rest. Data recorded during the performance of dynamic tasks was visually inspected by the field expert to assess abnormalities in the magnitude and the shape of the EMG amplitude modulation. An ordinal scale ranging from 0 to 10 was used to generate scores of the severity of the observed abnormalities in the EMG activity patterns. Herein, we refer to this set of scores as primary labels. In addition, the field expert generated scores of the severity of laterality in the EMG activity observed during static and dynamic tests. We refer to these scores as secondary labels. For all primary and secondary labels, regression models were implemented based on data features derived from the raw EMG recordings as well as the EMG envelope times-series.

RESULTS: We used the primary and secondary labels generated by the field expert as gold standard and measured the accuracy of the estimates generated by the regression models using the root mean square error (RMSE). The RMSE of the estimates generated by the regression models for the primary labels for the static tasks ranged from 0.61 to 0.89 for the severity of spams and from 0.66 to 0.92 for the severity of aberrant activity levels. The RMSE of the estimates of the secondary labels for the static tasks ranged from 0.66 to 1.12 for the severity of the laterality of spams and from 0.80 to 0.99 for the severity of the laterality of aberrant activity levels. The RMSE of the estimates generated by the regression models for the primary labels for the dynamic tasks ranged from 1.35 to 3.73 for the severity of aberrant magnitudes of the EMG amplitude modulation and from 1.29 to 3.01 for the severity of aberrant shapes of the EMG amplitude modulation. Finally, The RMSE of the estimates of the secondary labels for the dynamic tasks ranged from 1.42 to 4.37.

CONCLUSION: The proposed regression model-based approach generates reliable estimates of the severity of aberrant muscle activity patterns as captured via visual inspection of the EMG recordings collected during the performance of functional tests.

REHABILITATION/REHABILITATION TECHNOLOGIES

PII.57 Effects of an ankle foot orthosis that can recreate dorsiflexion of the metatarsophalangeal joint on gait in a child with spastic hemiplegia cerebral palsy

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BACKGROUND AND AIM: Ankle-foot orthoses (AFO) with an oil damper can improve heel-rocker function during the loading response phase of gait; however, an incomplete push-off movement during the pre-swing (PSw) phase remains a major issue. A new AFO that can recreate dorsiflexion of the metatarsophalangeal joint was produced experimentally using soft carbon fiber reinforced plastics. Therefore, the aim of this preliminary study was to assess the effects of this newly developed AFO on gait.

METHODS: The study participant was a 7-year-old boy with spastic hemiplegia cerebral palsy. This research study was conducted with the approval of the Osaka Prefecture University research ethics committee (2015-117). By using a motion analysis system that was synchronized with a force plate, 3 gait tasks were performed 5 times by the participant while walking barefoot or using the newly developed AFO or the conventional AFO. Then, the temporal, kinetic, and kinematic data were collected. To compare the sampled data, one-way analysis of variance with post hoc multiple comparison was used. The statistical significance was set at a p value of 0.05.

RESULTS: The peak vertical ground reaction force (GRF) at the PSw terminal phase was not significantly different between barefoot and the conventional AFO. Compared with the use of the conventional AFO, use of the newly developed AFO significantly increased the vertical GRF ($p < 0.01$).

CONCLUSIONS: These findings demonstrate that the newly developed AFO may help to perform gait more efficiently.

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PII.58 Effects of subliminal vibration on tactile perception discrimination thresholds

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BACKGROUND AND AIM: Stochastic resonance has been found to improve the scores of non-linear systems by adding a particular amount of white noise to the sensory system, and vibrational stimuli have been used in strategies toward fall prevention among elderly individuals. While the underlying mechanisms for the efficacy of this remain unclear, improvements are thought to occur through effects on the sensory input system and postural regulation functions. Against this backdrop, the present study examined how tactile perception on the underside of the foot and the tactile pressure sense of two-point discrimi-nation were affected by vibrational stimuli.

METHODS: Subjects were 12 healthy adult males (mean age, 20.7±0.9 years), to whom vibrations were applied at the base of the fifth metatarsal bone at a frequency of 225 Hz and output of 90% of the vibrational threshold (vibrational acceleration: 0.21-0.52 m/s2, mean 0.34±0.1 m/s2). We measured the tactile perception longitudinally along the mediolateral edge of the plantar aspect of the foot, and tested the two-point discrimination. Paired t-test was used for statistical analysis, with statistical significance assumed at $p<0.05$.

RESULTS: We found no significant difference in the tactile perception threshold. Application of vibrational stimuli significantly shortened the distance between two differentiable points in the two-point discrimination ($p<0.01$).

CONCLUSIONS: The stimulus conditions used in the present study were found to be appropriate for use as white noise levels for the sensory system on the underside of the foot, and suggest the possibility for increasing an individual's capacity to integrate and process sensory information from two different points on a given body part.

PII.59 Myoelectric pattern recognition driven robotic hand assisted training after spinal cord injury

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BACKGROUND AND AIM: Robot-assisted therapy is recommended for neurorehabilitation. Driving a robot using subject's voluntary input can enhance therapeutic effects while promoting motor learning as well. Various electromyography (EMG)-driven robots and exoskeletons have been developed for neurorehabilitation, primarily based on a conventional on-off or proportional control strategy. Such a strategy maps a single muscle (or a pair of muscles) to a single degree-of-freedom (DOF). However, most functional hand tasks require complex temporal and spatial coordination of multiple muscles, which is known as dexterity. It is therefore not feasible to regain dexterity through conventional strategies. To overcome this limitation, myoelectric pattern recognition techniques have been developed to extract more complex motion control information from EMG signals, which can be used to control multiple DOFs.

METHODS: A myoelectric pattern recognition framework was developed in order to control a therapeutic robotic hand. The algorithm framework is able to detect and recognize the subject's hand motion intents in real time based on EMG signals acquired by 7 EMG electrodes placed on his hand and forearm. The recognition results are mapped to control commands, driving the robotic hand to perform the same motion as the subject intends to do. Thus, the robotic hand can assist the subject to accomplish intended hand motions. The current version of the robotic hand can perform six different movement patterns, including hand closing (HC); hand opening (HO); thumb, index and middle fingers closing (TIMC); thumb, index and middle fingers opening (TIMO); middle, ring and little fingers closing (MRLC); and middle, ring and little fingers opening (MRLO). Subjects were invited to participate in a 20-visit experiment. Each visit included four 10-minute robot-assisted training sessions, in which the subject performed hand motions repeatedly with the assistance of the robotic hand that was triggered by his motion intents. Clinical assessments were performed before and after the 20-visit experiments in order to measure the outcome. 6 incomplete spinal cord injury subjects (all males, 52.8±12.5 years, 11.8±10.3 years after injury) participated in this study. Their scores in Part B of the Graded Redefined Assessment of Strength, Sensibility and Prehension test (GRASSP) were between 0 and 9.

RESULTS: 5 subjects obtained higher scores in Box & Block test and GRASSP Part B after training, respectively, indicating improved hand functions. All 6 subjects got increment on their grip force, and 2 subjects got increment on pinch force. The average improvement was 3.7±2.8 points for Box & Block test, 1.2±1.7 points for GRASSP Part B, 2.3±2.3 kg for grip force, and 0.3±0.4 kg for pinch force.

CONCLUSIONS: The results show that it is an effective way to improve hand functions after spinal cord injury.

PII.60 Analysis of functional role of the human rectus femoris muscle by frequency analysis of EMG

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BACKGROUND AND AIM: The animals including humans have the mono-articular muscle crossing single joint and the bi-articular muscle crossing two joint. It was shown in bi-articular muscle of the animals that there was the region-specific functional role within a muscle. The rectus femoris muscle is known as bi-articular muscle. From the viewpoint of rehabilitation medicine, the importance of RF is pointed out. Watanabe et al (J Electromyogr Kinesiol 2012;22:251-258) showed the region-specific functional role in the human rectus femoris muscle by using High surface electromyography. The purpose of this study was to conduct the qualitative evaluation of the region-specific functional role in the human rectus femoris muscle by using the frequency information of the electromyogram.

METHODS: Subjects were the health adult males in twenties. The subject sat down on a chair and performed a maximum effort of the knee extension and a maximum effort of the hip joint flexure. The electromyogram of the rectus femoris muscle were measured by using the multi-channel bar electrodes. We performed the frequency analysis using the Matching pursuit method and compared the distal part with the proximal part of the human rectus femoris muscle.

RESULTS; The frequency distribution of the electromyogram of the proximal part of the human rectus femoris muscle showed a different pattern by knee extension and the hip joint flexion. In the distal part, the patterns were different.

CONCLUSIONS: The muscular activity of the rectus femoris muscle, which was bi-articular muscle, was compared with the knee extension by hip joint flexion by using the frequency analysis of the electromyogram. The result showed that the frequency distribution was different in proximal part and the distal part of the human rectus femoris muscle. We thought that there might be difference in the type of the active motor unit.

PII.61 Electrocardiographic and functional near-infrared spectroscopic analysis of effects of tactile stimulation on relaxation

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BACKGROUND AND AIM: Tactile stimuli such as stroking the back when feeling tense is calming and pain can be relieved by touching or stroking painful areas. Appropriate tactile stimulation is often applied in clinical practice for relaxation, although whether it actually does so has not been scientifically proven. The present study aimed to determine the effects of tactile stimulation on healthy persons using electrocardiography (ECG) and functional near-infrared spectroscopy (fNIRS).

METHODS: The effects of tactile stimulation were determined in seven healthy male college students (mean age, 20.4±0.7 y) who were forced to hear the sound of a fork scratching glass. The participants rested in seat for 30 seconds and then heard this unpleasant sound with headphone for 30 seconds. R-R intervals and oxy-hemoglobin (oxy-Hb) concentrations around the orbitofrontal cortex were measured after receiving tactile stimulation for 120 seconds (stimulated) or not (control). We measured R-R intervals and oxy-Hb concentrations using ECG and fNIRS, respectively, during four 30-second intervals and then the calculated averages in the last 10 seconds were taken as representative. Tactile stimulation comprised stroking the 1st to the 12th thoracic vertebrae with a brush (width, 7 mm; length, 90 mm; thickness, 24 mm) at a rate of five times per 10 seconds, with a force sufficient to cause the brush tip to collapse a little. Changes in R-R intervals and the oxy-Hb concentrations with or without tactile stimulation during the four intervals were evaluated by two-way repeated ANOVA and Tukey's multiple comparison tests.

RESULTS: The main effects of tactile stimulation on R-R intervals and oxy-Hb concentrations significantly differed ($F=4.53$, $p<0.05$ and $F=11.50$, $p<0.005$, respectively), but not among the four 30-second intervals. The R-R interval was significantly longer in the stimulated group than the control group ($p<0.05$). More specifically, the R-R interval immediately decreased in both groups while hearing the unpleasant sound, thereafter did not change in the control group, but became prolonged in the stimulated group. The oxy-Hb concentration was significantly lower in the stimulated group ($p<0.05$). More specifically, the oxy-Hb concentration continued to increase in both groups for a while after hearing the unpleasant sound, thereafter, did not change in the control and began to decrease in stimulated groups.

CONCLUSIONS: The R-R interval reflects the action of autonomic nerves, and its extension implies a relaxation effect resulting from parasympathetic action. A reduced oxy-Hb concentration in the periphery of the orbitofrontal cortex, which is closely connected to the limbic system that controls emotion, suggests that tactile stimulation calms mood and emotional control is not needed.

PII.62 Effect of transcranial direct current stimulation in the treatment of low back pain

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BACKGROUND AND AIM: There is little evidence of the influence of transcranial direct current stimulation (tDCS) for low back pain (LBP). Furthermore, differences of the effect of tDCS on different cortical areas are still poorly understood for LBP. Hence, the aim of this single-blinded study was to evaluate the effects of tDCS of different cortical areas- bilateral primary motor cortex (M1), bilateral dorsolateral prefrontal cortex (DLPFC), and sham stimulation (total 5 conditions)- for LBP.

METHODS: Fifty university students with LBP were randomly assigned to 5 groups of 10 people. We examined the following outcomes to evaluate changes immediately before and after, 1 hour ,2 hours, 24 hours, and 1 week after tDCS: pressure pain thresholds (PPT) and pressure pain tolerance threshold (PPTT) of painful sites, LBP disability, pain catastrophizing, pain intensities, unpleasantness and anxiety. LBP disability was measured using Japanese version Oswestry Disability Index (ODI). Pain catastrophizing was measured using Pain Catastrophizing Scale. Pain intensities was measured using McGill Pain Questionnaire. Unpleasantness was measured using Visual Analogue Scale (VAS). Anxiety was measured using State-Trait Anxiety Inventory. Regarding tDCS, the anode electrode was placed above right or left M1 and right or left DLPFC, and the cathode was placed over the supraorbital area on the opposite side. A constant current of 2 mA intensity was applied for 20 minutes. For sham stimulation, the electrodes were placed in the same positions as for anodal DLPFC stimulation, but the stimulator was turned off after 30 s of stimulation. Using the value before tDCS as the baseline, the rate of change of the parameters in each period was calculated and compared. Statistical analysis was performed by the Non-parametric Kruskal-Wallis test for within group comparison and Friedman test for comparison between groups.

RESULTS: PPT ratings immediately after anode tDCS on left DLPFC were increased significantly compared with post-sham tDCS ($p<0.05$). VAS ratings for pain intensity of 24 hours after anode tDCS on within group comparison of left M1 were decreased significantly compared with immediately after ($p<0.05$). VAS ratings for unpleasantness of 2 hours and 24 hours after anode tDCS on Within group comparison of right DLPFC were decreased significantly compared with immediately after ($p<0.01$). There were no significant differences in other outcomes.

CONCLUSIONS: We could not find a tendency of the site or laterality of effective stimulation on LBP from the results of our study. However, the results of our study is in line with earlier studies that M1 is primarily involved in sensory aspects of pain, and DLPFC is primarily involved in sensory and emotional aspects of pain.

PII.63 Effects of long-term Galvanic Vestibular Stimulation (GVS) on blood pressure fluctuation at posture change

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BACKGROUND AND AIM: The vestibular system plays an important role in control of arterial pressure during posture transition. To examine this role in human subjects, previous study compared changes in arterial pressure upon head up tilt with and without galvanic vestibular stimulation (GVS), which is considered to obscure vestibular input, and showed that GVS enhanced arterial control at the onset of head up tilt [1]. Recently, GVS applied for 20min to improve posture or standing balance in rehabilitation setting [2]. In this study, we examined that whether long-term application of GVS will induced change in control of arterial pressure during posture transition.

METHODS: Ten healthy men aged 19.9±0.9 were included in this study. They completed three types of GVS (left cathode GVS, right cathode GVS, sham GVS) applied in a random order 24hours apart. GVS was applied at below somatosensory threshold (0.8 - 1.0mA) for 20min. Sham GVS was only placed electrode but current not delivered. Subjects were instructed to be in a supine position on the bed, then 3min after start stimuli instructed to stand up and hold 2min, after that instruct to be in a supine positon again. This operation was repeated 4 times during GVS. Systolic, diastolic, mean blood pressure and heart rate were continuously measured by finger plethysmography (Finometer MIDI, MLE1054-V; Finapres Medical Systems B.V., Amsterdam, the Netherlands)?The data were averaged and used for statistical processing which were obtained for 10sec before and 20sec after stand-up.

RESULTS: We observed that in all conditions, systolic, diastolic and mean blood pressures decreased statistically significantly when standing from the supine position in the first to fourth rounds. The heart rate increased statistically significantly. Between the first and fourth time, only the right cathode GVS had a difference in systolic, diastolic and mean blood pressure reduction after standing. The heart rate also differed in right cathode GVS. When comparing between the respective conditions, significant differences were found at the 1st, 2nd and 3rd round in the variation of the systolic blood pressure.

CONCLUSIONS: Results from this study suggested that the GVS affects blood pressure fluctuations associated with postural changes. In particular, it was shown that the variation of the right cathode GVS varies with the lapse of time when the body position conversion is performed for 20 minutes. This finding suggests that it is necessary to pay attention to blood pressure fluctuation when utilizing GVS in rehabilitation.

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PII.64 Does gender affect detection threshold and pain threshold in subdermal electrical stimulation?

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BACKGROUND AND AIM: Noninvasive electrical stimulation has been applied in rehabilitation related health care for e.g. analgesia, circulation, neuromuscular activation or generation of artificial sensory feedback. Gender difference in detection threshold (DT) and pain threshold (PT) has been previously found in surface electrical stimulation which can influence the rehabilitation process. However, it is unknown whether the gender difference also exists in subdermal stimulation. The aim of this study was therefore to investigate the gender effect on DT and PT in subdermal electrical stimulation.

METHODS: 30 healthy subjects (19 males and 11 females, 26.70 ± 5.07 years old) were recruited from Aalborg University, Denmark. The protocol was approved by The Danish Northern Region Committee on Health Research Ethics (N-20160021). One surface electrode (Ambu Neuroline 700, 20 mm × 15 mm) and one subdermal electrode (Teflon-coated stainless steel with 5 mm tip exposed, inserted subdermally using a 25-gauge hypodermic needle) were placed at the middle of the posterior non-dominant forearm of the subject to deliver the electrical stimulation. Biphasic, rectangular, symmetric waveform with a phase duration of 100 us stimulus was used. DT was measured using a staircase procedure and PT was measured using the method of limit.

RESULTS: The mean and standard deviation (SD) of DT and PT in the female and male group, as well as the effect size of the difference between groups are presented in Table I. The mean DT was higher for males than females in both surface stimulation (5.11 mA vs 3.91 mA) and subdermal stimulation (1.08 mA vs 0.57 mA). The mean PT was higher for males than females in surface stimulation (17.38 mA vs 14.37 mA), but at similar level as subdermal stimulation (5.57 mA vs 5.34 mA). The differences were further quantified by calculating the effect size of the difference between the female and male groups. The effect sizes of DT for both surface stimulation and subdermal stimulation were over 0.5 (0.64 and 0.71). The effect size of PT for surface stimulation was 0.44, however, the effect size of PT for subdermal stimulation was very low (0.05).

CONCLUSIONS: Moderate effect sizes between the females and the males in both surface and subdermal stimulation suggest gender affected DT in both types of stimulation. Substantially small effect size between the females and the males was only observed during surface stimulation, suggesting that gender affected PT only in surface stimulation, but not subdermal stimulation.

TABLE I
Mean, SD of both gender and effect size between gender

	DT				PT			
	Surface		Subdermal		Surface		Subdermal	
	Male	Fe-male	Male	Fe-male	Male	Fe-male	Male	Fe-male
Mean	5.11	3.91	1.08	0.75	17.38	14.37	5.57	5.34
SD	2.06	1.49	0.53	0.31	8.00	4.13	3.40	5.34
Effect size	0.64		0.71		0.44		0.05	

PII.65 A Treatment with Roller-Massager Improves the Oxygenation of the Upper Trapezius Muscle: A Single-Subject Research Design Study

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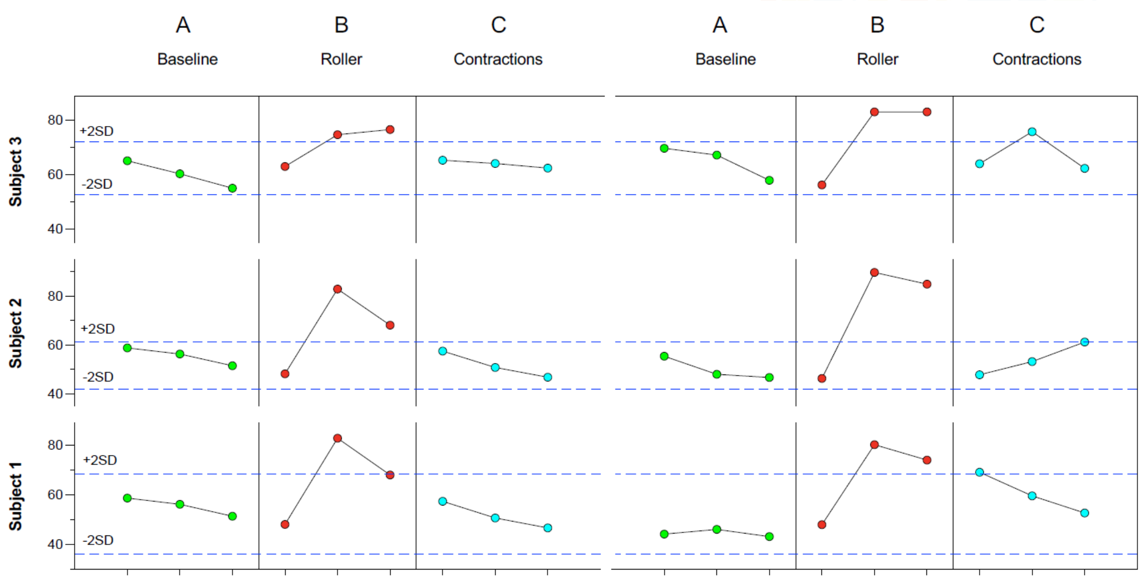
BACKGROUND AND AIM: The Roller Massager is a dense foam cylinder with a wavy surface that clinicians use to increase muscle extensibility and reduce muscle pain. Even though some authors have suggested that the friction occurring during the cycling compression might induce an increase of muscle temperature and change the fascia into a more liquid state, the underlying mechanism of the Roller Massager is still unclear. The purpose of this study was to investigate the effect of a single treatment of roller-massager on the oxygenation of the upper trapezius muscle. It was hypothesized that the Roller Massager treatment increases the muscle oxygenation.

METHODS: An ABCABC single-subject design with multiple-treatment was used to examine the effects of two interventions. Three healthy volunteers (1,2,3) underwent six consecutive sessions, 2 to 4 days apart. During each session, the upper trapezius muscle oxygenation (SmO2) was measured three times using the Near Infrared Spectroscopy (NIRS). SmO2 of the upper trapezius muscle was measured according to a standard protocol including: subject's positioning, NIRS placement, duration of the NIRS measurements and intra-session timing for NIRS measurements. Session A did not include any treatment and was used to identify the baseline values of the SmO2. Session B included a 3 minutes Roller Massager treatment of the upper trapezius muscle. The Roller Massager device included a sensor to control the pressure exerted (approx. 2kg) on the muscle. Session C included three consecutive submaximal isometric contractions of the upper trapezius muscle. During session B and C, SmO2 was recorded before the treatment, immediately after treatment and 8 minutes after treatment. SmO2 values were assessed visually and statistically by using the two-standard deviation band method.

RESULTS: The SmO2 values were stable during the two A sessions and during the pre-treatment measurements of sessions B and C. The SmO2 significantly increased after the Roller Massager treatment and persisted for 8 minutes. No significant SmO2 improvement was observed after the submaximal isometric contractions.

CONCLUSION: A single treatment of Roller Massager improves the oxygenation of the upper trapezius muscle.



PII.66 Inter-Structural Release Can Alter Shear Modulus of Resting Non-Symptomatic Muscle

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BACKGROUND AND AIM: Application of an inter-structural release (ISR) procedure to skeletal muscles is believed to attenuate assumed adhesion between muscles and alleviate perceived stiffness or associated pain based on subjective assessment, whereas objective evidence is limited about the effect of ISR on mechanical properties of muscles. The purpose of this study was to understand the effect of ISR on shear modulus of resting skeletal muscles in non-symptomatic healthy young adults.

METHODS: Non-symptomatic muscles in the right leg were tested on two days with an interval of at least one week in nine healthy young men (age: 21.9 ± 1.4 years, height: 170 ± 6.6 cm, body mass: 64.3 ± 4.0 kg). By means of ultrasound shear-wave elastography, shear modulus along muscle fascicles was measured in the resting peroneus longus and soleus muscles before and after ISR or standard massage depending on the day. On one day, ISR was applied across the length of these muscles for 30 min. Using the thumb and the index finger, ISR targeted the superficial fascia followed by the deep fascia between the peroneus longus and soleus. On the other day, standard massage was applied to the same muscles with the similar manual pressure as used in ISR for 30 min. These interventions were applied to the same leg in random order. To obtain shear modulus under various passive tension due to muscle stretching, the ankle joint angle during measurement was varied passively from 30° inversion to 20° eversion with the increments of 10°. Spatial average of shear modulus in each muscle was quantified at each joint angle. The amplitude of surface electromyogram (EMG) was also monitored and quantified to ensure the resting neural state of the muscles during measurement.

RESULTS: As the ankle joint position was passively varied toward inversion, mean shear modulus increased in both muscles ($P < 0.01$). After ISR, but not massage, mean shear modulus was increased acutely by 11% at 30° inversion (i.e. most stretched posture) from 53.3 ± 13.9 to 59.1 ± 16.2 kPa ($P < 0.01$) in the peroneus longus. There was no significant effect of intervention or time on mean shear modulus in other joint angles or soleus. No apparent EMG activity or significant change was found on EMG amplitude.

CONCLUSIONS: These results objectively demonstrate that ISR can acutely alter shear modulus of a resting non-symptomatic muscle in the direction of muscle fascicles in young adults. The increased shear modulus in the most stretched posture after ISR may imply that potential inhibition of passive muscle stretching due to parallel muscle adhesion may be disinhibited by ISR.

POSTER PRESENTATIONS

Monday, 2nd July

3 Poster Session III, Monday July 2nd

BIOMECHANICS

PIII.1 Phase-dependent gait variability in self-paced treadmill walking

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The previous researches have suggested that gait variability generates as a process to react both internal (i.e., neuromuscular noise) and external (e.g. obstacle) perturbations. Although gait variability is often interpreted as movement error, recent studies have shown that this phenomenon ensures the stability of gait motor control. The purpose of the present study is to explore the functional variability of kinematic gait-related parameters (i.e. joint angles, moments, and powers) in relation to the different phases within a gait cycle, so called, phase-dependent gait variability. The total of twenty three participants were asked to walk in the feedback-controlled treadmill (Gait Real-time Analysis Interactive Lab: GRAIL, Motek Medical, the Netherlands), that allows the subjects to in real-time adjust the belt speed, so called self-paced (SP) walking, with an immersive virtual reality (VR) environment. This environment gives subjects more natural and efficient visual cues, which are perceptually consistent with self-controlled gait speed. Twenty-five reflective markers were placed on anatomical landmarks using the Motek Human Body Model lower-body marker set. To assess differences with respect to the variability of different joint angles, moments, and powers (e.g. hip, knee, and ankle flexion-extension), the statistical parametric mapping method was used. As a result, the highest peaks of the time-continuous variability of ankle, knee, and hip joint flexion-extension angles were found in the swing phase of the gait. However, in the swing phase, the variability of ankle and knee joint angles were higher compared to those of hip angle. Furthermore, we also found the lowest peaks of the variability of those joint angles during mid swing phase where the minimum toe clearance was identified. In conclusion, we demonstrated that the phase-dependent functional gait variability existed on particularly in ankle and knee joints during the swing phase, suggesting that these variabilities may contribute to ensure the stability of human gait motor control.

PIII.2 Differentiating Lifting Fatigue Waveforms using a Principal component approach

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Background and Aim. Prolonged lifting may be associated with an increase injury risk due to fatigued muscles. This study investigated the neuromuscular changes of three different fatiguing protocols during prolonged lifting. To reduce the dimensionality of the assessment involved with examining eight muscles sites, a principal component analysis (PCA) was used to differentiate the EMG waveforms of the three fatiguing protocols. PCA has been used previously as a robust method for assessing motion waveforms1,2 and neuromuscular adaptations during lifting3.

Methods: Thirteen university students performed a lifting task consisting of lifting a box weighing 10% of a lift specific maximal voluntary isometric exertion (MVIE) from the floor to a chest height shelf at a rate of 6 lifts per minute. The lifting task was performed under three different fatiguing conditions (general, back and shoulder) randomized on separate days. Prior to the lifting conditions, the participants completed trunk extension and shoulder flexion MVIE. General fatigue consisted of 75 minutes of consecutive lifting. Shoulder and back fatigue consisted of 5 minutes of baseline lifting followed by a shoulder or back fatigue protocol, respectively and then 5 minutes of post-fatigue lifting. Trunk extension and shoulder flexion MVIE protocols were repeated at the end of the lifting trials. Electromyography electrodes were placed on the anterior deltoid (AD), posterior deltoid (PD), upper trapezius (UT), long head of biceps brachii (BI), lateral head of triceps brachii (TRI), erector spinae at the thoracic (T8) and lumbar (L5) levels. Raw EMG was filtered using band pass 20-450Hz butterworth 4th order filter, with a notch filter applied at 59 to 61 Hz. The signal was rectified and then smoothed using a rectangle half width using a moving average method. Waveforms were normalized to 101 time points before a PCA was used to extract modes of variation between the general fatigue, the back specific and the shoulder specific fatigue states.

RESULTS: The general fatigue protocol produced significant peak EMG decreases in the AD, BI and T8 muscles. The shoulder fatigue protocol resulted in a significant increase in peak BI activity. For all muscles, except the biceps, the variation in the EMG waveforms could be captured within two principal components. The first principle component captured a magnitude difference in muscle activity. The shoulder fatiguing protocol demonstrated a larger AD and BI than the other two fatiguing protocols. The largest variation captured was in performing the load placement to the shelf. Similarly, the UT had higher activation on load placement for the shoulder and general fatiguing protocol compared to the back fatigue.

CONCLUSION. The shoulder fatiguing protocol appeared to have the largest effect on lifting technique accommodation as related to the muscle activation patterns of the upper extremity.

PIII.3 Kinematic of the Shoulder During Two Humeral Head Procedures

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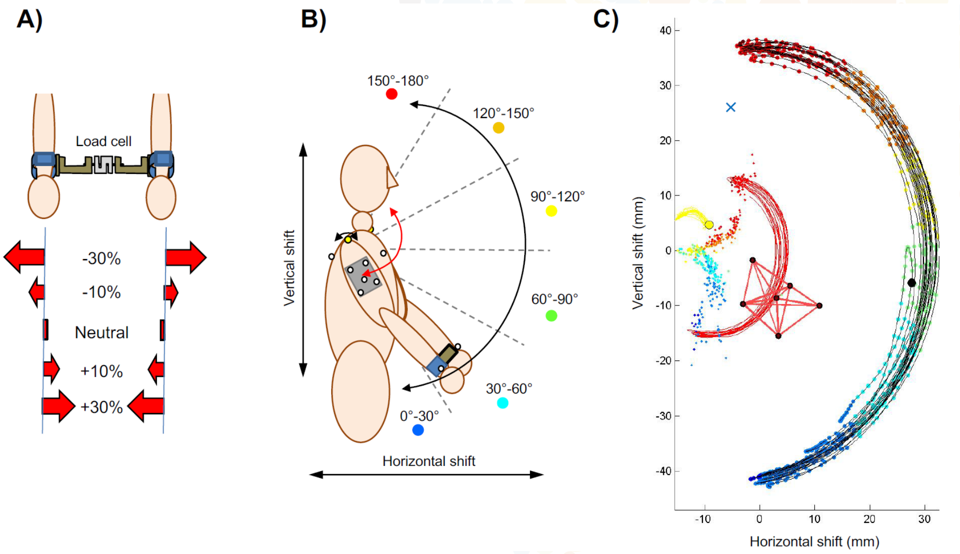
BACKGROUND AND AIM: The Shoulder Symptom Modification Procedure (SSMP) involves a series of clinical procedures that are applied to the shoulder as the patient performs movements that reproduce symptoms. The aim of the SSMP procedures is to reduce or alleviate symptoms and techniques identified to accomplish may then be used in patient management. The reason these procedures may reduce symptoms is not known, although potential mechanisms include; changes in motor control, changes in soft tissue strain, joint displacement, pain neuromodulation, placebo, etc. SSMP techniques includes a series of procedures hypothesised to influence the position of the humeral head on the glenoid fossa. One method of achieving this is sustaining contractions of the shoulder external rotators, or shoulder adductors/internal rotators during arm elevation. The aim of this was to investigate if activation of the shoulder external or internal rotators during arm elevation produces a shift of the instantaneous center of rotation (ICR) of shoulder.

METHODS: Twenty healthy participants (31.2 ± 8.2 years) volunteered for this investigation. An optoelectric motion capture system (120fps) was used to detect shoulder movement. Five markers were positioned on each arm; two on the wrists, two on the lateral border of the acriomion and one on the sternum. Participants were asked to perform an elevation of the arms with their wrists fixed to a bar incorporating a load cell. The load cell was connected to a visual feedback display that provided an indication of the percentage of maximal voluntary contraction (MVC) during the contraction of the shoulder external rotators or shoulder internal rotators / adductors. Subjects were asked to perform five sets of 10 arm elevations, maintaining a constant force of -30%, -10%, 0%, +10% and +30% of their MVC. Negative values indicated and external rotation force during elevation, and positive values, internal rotation/adduction (Fig.1A). The arm movements were divided in angles of 30 degrees (Fig.1B). The ICR of each shoulder was computed with respect to the chest (Fig.1C). One-way Analysis of Variance (ANOVA) was used to observe the behavior of the IRC coordinates at different force levels.

RESULTS: No significant differences have been observed regarding the shoulder ICR shift between left and right. A significant anterior shift of shoulder ICR was observed during internal rotation/adduction at +10% MVC and +30% MVC with respect to %0 MVC. No significant shift of shoulder ICR was observed during external rotation at -30% MVC and -10% MVC with respect to %0 MVC.

CONCLUSION: During the arm elevation, a contraction of the shoulder internal rotators/adductors can induce an anterior shift of the ICR of the shoulder. Clinical changes during these procedures, may relate to changes in shoulder kinematics. More research, including research in people with symptoms is needed.



PIII.4 The role of head movement in human balancing

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Budapest University of Technology and Economics

BACKGROUND AND AIM: Human is an unstable system unless a control system is continuously acting. This control system is characterized by the balancing ability. The goal of this research is to determine new parameters, derived from the movement of the head and the platform used in sudden perturbation tests, which characterizes the balancing ability with great reliability.

METHODS: Sudden perturbation tests were carried out on a PosturoMed© device with 11 healthy people (average age: 22.82±1.72 years; average height: 179.42±10.83 cm; average weight: 80.65±19.90 kg). The measurements involved 6 different positions combined from the eye, leg and spring conditions (double leg stance with eyes open and closed with both 4 and 8 springs in the system and single leg stance on both legs with eyes open with 4 springs in the system). The participants were measured on 4 occasions. The occasions were 3, 9 and 3 days apart from each other. The participants were measured 10 times in every position. During the measurements the 3D-coordinates of the head and the platform were recorded by the Optitrack© Motion Capture camera system in the Motion Laboratory of the TU Budapest. The parameters included known and new parameters calculated from the movement of the platform or from the movement of the head or from both the movement of the head and the platform. The ratio of the successful/unsuccessful measurements, the significant differences between the occasions of the measurements, the correlation of the parameters and the reliability of the parameters are analysed, for which the Intraclass Correlation Coefficient (ICC), the covariance of variation (CV) and the CV compliance rate (CVCR) calculated.

RESULTS: 8 reliable parameters calculated from the movement of the platform and 2 new reliable parameters calculated from both the movement of the head and the platform were found. The tests also concluded, that more parameters could reliably characterize the measurements done with 4 springs in the system, in double leg stance with eyes open and closed and also with 8 springs in the system, in double leg stance with eyes closed than the measurements done with different settings. The 10 reliable parameters showed in at least 6 of the 11 analysed cases significant differences.

CONCLUSION: It can be stated that the balancing ability could be analysed by motion of platform and by head. The research proves that the role of head movement is a determinant factor in human balancing and new parameters were found reliable in characterizing the balancing capability which were not investigated before. It is recommended to take these new parameters into consideration in future researches connected to balancing.

ACKNOWLEDGEMENT: This work was supported by the Hungarian Scientific Research Fund OTKA [grant number K115894].

PIII.5 Reliability of Spatial Representation of Soleus Muscle Activity Using High Density EMG and Different Electrode Grid Orientations

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BACKGROUND/ AIM: Surface electromyography (EMG) is used to study neuromuscular function and coordination and electrode position can be challenging for those muscles with complex architecture and non-uniform EMG distribution [1]. The human soleus muscle is a complex, multi-pennate muscle and thus electrode positioning is critical [2]. The purpose of this study was to examine within and between day reliability of peak torque and spatial parameters of soleus muscle high density EMG (HDEMG) during ankle plantar flexion and to assess changes in spatial distribution between two recommended electrode positions to determine the effect of HDEMG grid orientation.

METHODS: Eleven adults (7 males and 4 females, mean age of 25.2 4.2 years old) completed three maximal isometric ankle plantar flexions using a Cybex Humac Norm (CSMI Inc., USA) isokinetic dynamometer. The participant returned to repeat the experiment one week later. HDEMG (8 rows X 4 columns of electrodes) data were collected (Trentadue, OT Bioelettronica) from two separate recommended locations. A 'medial' grid was placed according to SENIAM guidelines at 2/3 of the line between the medial condylis of the femur to the medial malleolus. A 'lateral' grid was placed on the lateral, posterior side of the lower leg [3]. Isometric torque and HDEMG spatial features (differential intensity, intensity and x- and y- centre of gravity) were compared. Intensity was calculated using all electrodes, while differential intensity used one pair of sensors from the central region of the grid [4].

RESULTS: Analysis of Variance (ANOVA) and Pearson correlations (r) were used to compare data. Within day reliability was moderate to good for differential intensity with $r = 0.79$ ($p=0.004$), intensity $r= 0.86$ ($p<0.001$), peak torque $r= 0.82$ ($p=0.002$) and centre of gravity (y) $r=0.62$ ($p=0.0417$). The between day reliability was stronger for peak torque ($r=0.79$, $p=0.004$) and centre of gravity measures (x direction) ($r=0.74$, $p=0.008$). Medial and lateral grid orientations were found to be correlated with differential intensity ($r=0.59$, $p=0.05$) and centre of gravity (x) ($r=0.66$, $p=0.027$).

CONCLUSIONS: Preliminary data suggests within data reliability was moderate to good for both torque and HDEMG spatial parameters. Torque, differential intensity and centre of gravity spatial parameters were reliable between days. In addition, electrode grid positioning did not affect the differential intensity and centre of gravity features of the HDEMG. However, we did not examine a central location or contractions of varying intensity. These should be investigated to determine the effect of the electrode grid orientation on EMG spatial distribution to ensure appropriate guidelines for electrode placement.

REFERENCES: [1] Botter et al.,Conf Proc IEEE Eng Med Biol Sci, 3460-3, 2015 [2] Reffad et al., Biomed Tech, 59(5) 399-411, 2014 [3] Criswell Cram's Introduction to Surface EMG 2nd ed., 2011 [4] Jordanic et al., J Neuroeng Rehab, 13(1), 2016

PIII.6 Multisegment Foot Mechanics During Walking in Children with Autism

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University of New Brunswick

BACKGROUND AND AIM: Autism is a developmental disorder that can affect motor skills such as walking. Previous research has shown deviations in foot movement during gait in children with autism compared to controls using simplistic mechanical models. To further understand foot mechanics in this population, the purpose of this study was to examine multisegment foot kinematics during gait in children using a complex model of the foot. Increased understanding of the relative motion of the small segments of the foot could aid in our understanding of foot mechanics and function in typical and atypical development.

METHODS: Sixteen children (12 male; 4 female; mean age = 10.4 ± 3.1yrs; mean height = 1.41 ± 0.16m; mean weight =39.2 ± 18.9kg) aged 6-16 years with ASD (Autism or Asperger's Disorder) participated in the study. This study excluded children who were toe walkers and/or currently wore orthotics. Control group data consisted of 18 children (12 male; 6 female; mean age = 10.9 ± 2.1yrs; mean height = 1.44 ± 0.12m; mean weight = 36.4 ± 13.9kg). A 12-camera Vicon T160 motion capture system (Oxford Metrics Group, Oxford, UK), sampling at 100 Hz, was used to track the three-dimensional trajectories of 34 reflective markers placed on the participant. The rigid body model consisted of five segments: 1) the shank, 2) the total foot (single rigid segment), 3) the calcaneus, 4) the midfoot, and 5) the forefoot. The hallux and metatarsal bones were modeled as line segments for the computation of planar angles. Euler angle data was analyzed using custom software created in Matlab (Mathworks, Inc). A series of one-way ANOVAs and post hoc analyses were used in SPSS to test for significant differences ($p<0.05$) in minimum and maximum joint angles between the autism and control groups.

RESULTS: Significant differences ($p < 0.05$) in mean maximum values of planar angles were found between the autism and control group. The autism group demonstrated decreased sagittal maximum hallux and second metatarsal angles, as well as increased medial longitudinal arch angles compared to the control group. Significant differences in mean maximum joint angle parameters for the autism group were also found for relative joint angles between the foot segments, including decreased dorsiflexion of the calcaneus with respect to the midfoot and midfoot with respect to the forefoot.

CONCLUSIONS: This study emphasizes the importance of using multisegment foot models in clinical populations. Studies examining the relative motion between foot segments could allow researchers and clinicians to further understand the differences in foot biomechanics and function in children with Autism. This may lead to the identification and evaluation of treatment plans to improve gait patterns, independence, and quality of life. Further studies are needed to examine differences in the role of the subsegments in stabilization of the foot during gait in autism as well as possible structural changes of the foot with development.

PIII.7 The Effects of Prolonged Lifting in the Emergency Medical Services

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[1]University of New Brunswick, [2]University of Waterloo, [3]Université de Moncton

Introduction: Sedentary behavior in the workplace has been an area of concern due to significant health risks of workers and the financial burden for employers. The development of type II diabetes, cardiovascular disease and obesity have been directly related to prolonged bouts of sitting in the workplace (Owen, 2008). Prolonged sitting may also have unintended consequences on the performance of subsequent work tasks like lifting. For example, paramedics are required to perform strenuous lifting tasks following prolonged sitting or driving. Paramedics are four times more likely to develop a workplace injury than the average worker (Maguire, 2013). Prolonged sitting is known to change lumbar spine stiffness (Beach et al., 2005), which may affect how the neuromuscular system functions to perform a lift, which may in turn affect the risk of injury. To date, the effects of prolonged driving on neuromuscular function during lifting performance are not well understood. The purpose of this research was to identify changes in muscular activation levels and low back injury risk associated with lifting performance before and following a prolonged bout of sedentary behavior (sitting and driving).

METHODS: Ten participants (N=10) were recruited for this study with a mean age of 28.4 (±4.3) years of age. Surface electromyography (EMG) electrodes were placed on upper body musculature to assess muscle activation levels changes on three muscle sites bilaterally: anterior deltoid, biceps brachii and erector spinae. To begin, the participants performed 3 sets of 3 maximum voluntary contraction exercises. They then performed 10 box lifts from the floor to a shelf of 0.75 meters in height. They were then asked to drive in a driving simulator equipped with ambulance software for 3 hours. The custom software allows the simulator to operate like an ambulance in regards to handling, braking and accelerating. Upon completion of the driving task, participants were then asked to repeat the lifting task immediately. Muscle activation levels were recorded during the 10 separate lifts.

RESULTS: When comparing pre and post drive root mean square (RMS) values of the EMG data, it was found that 30% of participants showed significant increases in anterior deltoid activation levels. Furthermore, it was also determined that 50% of participants showed significant increases in biceps brachii activation levels. Lastly, 70% of participants showed significant increases in erector spinae activation levels.

CONCLUSION: This research study suggests that lifting requires a greater amount of muscle activity when performed after a prolonged bout of simulated driving relative to the pre-driving condition. Increased activation could increase the risk of injury associated with lifting in an occupational setting. Further research is needed to advance our understanding of musculoskeletal injuries after bouts of sedentary behavior in the workplace.

PIII.8 Effect of force plate coverings on vertical ground reaction forces

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BACKGROUND AND AIM: To increase ecological validity when researching the kinetics of sporting movements a covering that replicates surfaces used in sporting competition, may be placed on top of a force plate. Standardised in vitro testing procedures that quantify the effect of a surface on impact force exist, but do not always translate to force measurements during human movement (Dixon et al, 2000). It has been demonstrated that when dropping an object onto a covered force plate, changing the object's mass, drop height or area of contact will alter the relative effect on force platform recordings (Nigg, 1990). Therefore to determine the effect of using a covering during human movement, replicating ground reaction force (GRF) data close to that expected in the movement of interest is appropriate. The aim of this study was to investigate the association between surface type and vertical force characteristics during a standardised drop test using conditions that replicate GRF data concomitant with sporting activities.

METHODS: Vertical GRF was measured by dropping a 2kg medicine ball onto on a 600 x 400mm Kistler 9286AA force platform (Kistler, Winterthur, Switzerland; 5000Hz) from two known heights (low: 61cm; high: 139cm). Four surface conditions were used; bare plate, no covering (Ba), vinyl floor covering (Vi), Mondotrack athletics track surface (Sp) (Mondo, Rugby, UK) and a multi-sport astroturf covering (As) (As Good As Grass, Preston, UK). Sixty trials were repeated for each height and surface. Peak GRF and rate of force development (RFD; slope of GRF from onset to peak force), were calculated. A 4 (surface) by 2 (height) repeated measure ANOVA was used to analyse the data.

RESULTS: With regards to GRF, there was a significant effect for surface and height (both $p < 0.01$) and a significant interaction effect ($p < 0.01$). At the high condition, GRF for Sp (2894.8 N) was greater than the three other surfaces ($p < 0.01$). A similar result was found for the lower height, with both Sp (1916.1 N) and As (1935.7 N) greater than Ba and Vi ($p < 0.01$). Sp and As recorded the highest GRF at the high and low condition, respectively. A significant effect for surface and height (both $p < 0.01$) and a significant interaction effect ($p < 0.01$) were also evident for RFD. At both higher (809615.0 N/s) and lower (556281.7 N/s) height Sp recorded a greater RFD compared to the other three surfaces ($p < 0.01$), a greater difference to the other surfaces observed for the high condition. Vi recorded the lowest RFD for low condition and Ba for the high condition.

CONCLUSIONS: The type of covering of a force plate significantly affects the magnitude of vertical GRF and RFD recorded. The Sp surface yielding the greatest GRF and RFD values. This needs to be taken into account when comparing results from studies carried out in laboratories with different plate coverings. Future investigations could examine the effect of plate coverings on horizontal components of GRF and RFD.

PIII.9 Adaptations in Foot-Ground Interactions During a progressive 12-week Running Intervention in Footwear with Reduced Cushioning

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University of Cape Town

BACKGROUND AND AIM: Running is one of the most widely practiced recreational activities due to its simplicity and accessibility. Although popular, it is associated with an alarmingly high incidence of injury. Recently, footwear specifications have been explored as a method to mitigate this incidence, but often result in ambiguous and highly individualised outcomes. Footwear with reduced cushioning has been found to result in kinematic adaptations that influence key kinetic variables that have been linked to running related injury. The aim of this study is to determine the influence of footwear with reduced cushioning on kinematic and kinetic variables of novice runners who perform a progressive 12-week running intervention. Additionally, the study aims to relate these adaptations to running-related injury.

METHODS: Fifty-four participants were recruited to take part in the study, with forty-four participants completing the 12-week running intervention. Participants were allocated into one of two groups, those wearing reduced-cushioned (RC, n=20) footwear and those wearing traditionally cushioned (TC, n=24) footwear for the duration of the 12-week running intervention. Three-dimensional biomechanical gait analysis was conducted at baseline, 6-weeks and 12-weeks. Key variables measured included foot strike angle (FSA), ground reaction force (GRF), initial loading rate (ILR), lower limb sagittal joint angles and spatiotemporal variables.

RESULTS: The results showed that no differences in FSA were found between the RC and TC groups prior to the intervention. However, the RC group were four times more likely to reduce FSA the course of the 12-week running intervention (OR = 3.89; $p = 0.035$). Further, in the RC group, changes in FSA were correlated to changes in ankle and knee angles, whereas no correlations were found in the TC group. The RC group was split into responders (n=14, those who presented with a decrease in FSA after 12-weeks), and non-responders (n=6, those who presented with an increase in FSA after 12-weeks). The responders showed a significant reduction ($p<0.01$) in GRF but showed no change in ILR over time. The reduction in GRF was not associated with a change in stride frequency or stride length. The non-responders in the RC group, as well as the TC group showed no significant changes in ILR and GRF over time. Changes in GRF were positively correlated to changes in ankle and knee range of motion (ROM) in the RC group ($p<0.05$), whereas no correlations between GRF and joint ROM existed in the TC group.

CONCLUSIONS: Running in footwear does promote a flatter FSA but does not result in the adoption of a forefoot strike pattern. Changes in FSA when wearing footwear with reduced cushioning may be governed by proximal joint control, and those who presented with a reduction in FSA after 12-weeks when wearing shoes with reduced cushioning showed a significant reduction in GRF which was not coupled with an increased stride frequency. This interaction between kinetics and spatiotemporal variables suggests that the accumulative load is reduced, which may ultimately reduce the risk of running related injury.

PIII.10 Multivariate analysis reveals effects of hop direction and leg on the biomechanics of a novel one-leg double-hop test for individuals with unilateral anterior cruciate ligament reconstruction

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BACKGROUND AND AIM: Recent evidence on one-leg cutting tasks with unanticipated maneuvers reports aberrant movement strategies associated with a risk of anterior cruciate ligament (ACL) injury. Therefore, we designed a novel double-hop test ultimately aimed at evaluation of knee rehabilitation after ACL injury. The test comprised of a forward hop followed by a diagonal hop (45°) performed in medial (UMDH) or lateral direction (ULDH) without prior planning of the cutting (hopping) direction. The study aimed to evaluate the effects of direction (UMDH vs. ULDH) and leg (operated vs. uninjured) on a large set of trunk and lower limb biomechanical variables observed during the test in individuals with a unilateral ACL reconstruction (ACLR) using multivariate analysis.

METHODS: Twenty nine individuals (age: 24.7±4.7 years, 21 females) with a unilateral ACLR (33.7±32.1 months post-ACLR) performed three successful UMDH and ULDH, respectively. An 8-camera 3-D motion analysis system, 56 retroreflective markers, and two force plates were used. Participants performed the diagonal hops based on a visual cue randomly denoting hopping direction presented ?300 ms before the land-and-cut maneuver. Trunk and lower limb biomechanical variables were calculated: at initial foot contact, deceleration (initial foot contact to peak knee flexion, phase 1) and acceleration (peak knee flexion to toe-off, phase 2) phases of the land-and-cut maneuver. Multivariate analysis based on orthogonal projections to latent structures was used to analyze 157 variables (peak angles and/or moments of the hip, knee, ankle and trunk, medio-lateral knee control, timing of events, angle-of-cut, decision-making time to plan hop direction, maximum height and speed of hops, etc.). This simultaneously allowed detection and statistical evaluation of systematic effects considering the whole profile of biomechanical variables.

RESULTS: No significant multivariate model for the interaction between hop direction and leg was observed. However, a significant model for hop directions (UMDH and ULDH) ($p < 0.001$), irrespective of legs, was observed, with 70 variables found significant with a false discovery rate (FDR) <0.050. Most of the significant variables were peak angles and moments of the hip, knee and ankle in one or more planes during both phases of the land-and-cut maneuver. In addition, a significant model for legs ($p=0.036$), irrespective of hop direction, was obtained with 3 variables found significant (FDR <0.050) - peak hip flexion (phase 1), adduction (phase 2), and extension (phase 2) angles.

CONCLUSIONS: Multivariate analyses may disentangle effects of hop designs on complex movement patterns, where hop direction significantly influenced a considerable number of biomechanical variables in our novel test in individuals with ACLR. Such hop tests seem useful to evaluate landing strategies, movement patterns and leg asymmetries in patient populations and controls of different performance levels.

PIII.11 Relationship and differences between kinetics parameters and center of pressure during gait with ankle bracing orthosis and barefoot

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BACKGROUND AND AIM: Ankle Bracing Orthosis (ABO) are used to immobilize the joint while providing heat and compression to the bones. ABO are frequently prescribed to assist with gait impairments in injured subjects. They are common in injury rehabilitation processes that affect the ankle, being made of rigid fabric such nylon or polypropylene [1]. They are indicated for ankle trauma with small fractures or without fracture, immobilization of the joint, postoperative synovitis, sprains or inflammations of the joint, weak muscles in the ankle, among others [2]. Recent studies have provided conflicting results as to whether ABO reduce the risk of falling (Cakar et al., 2010; Guerra Padilla et al., 2011; Wang et al., 2007). Other studies have found no difference in clinical balance scores (Park et al., 2009; Wang et al., 2005) or in static or dynamic weight bearing tasks when wearing an ABO (Simons et al., 2009). Although, no study has used quantitative measures to assess the influence of ABO on dynamic balance during walking and running. Therefore, the aims of the present paper were (1) compare the barefoot and ABO gait (2) evaluate the effects of ABO on gait kinetics and COP of the foot during gait.

METHODS: Ten male subjects were included in this study (age: 28.3, SD = 1.6 years; mass: 65.7, SD = 4.9 kg; height: 1.74, SD=0.8m). Five persons of participant worn the ABO (left foot). An six-camera infrared Vicon motion analysis system, including two force plates, tracked and recorded the position of the reflective markers at 100 Hz. Vicon Nexus software collected the data on the kinetic parameters of hip, knee and ankle from the force plates and marker positions. The COP, operationally defined by the location at which the GRF crosses when a subject steps on the force plates, was determined by using the markers positioned on the foot and the force plate data. All data were subsequently exported for analysis to Vicon Polygon 3.5.1 software and to a custom-written MATLAB (MATLAB, 2016) program.

RESULTS: As shown in Figure 1 (A & B), worn ABO resulted in a significant shift in the COP parameters. Comparisons of the COP measures between barefoot and ABO indicated a significant shift in different stage of stance phase. This shift was significant at 51% and 60% gait cycle and also in the final stages of gait. Figure 1 (C & D) represents the mean and peak values of the lower joint kinetics in normal and ABO gait. No significant joint force differences between conditions are illustrated. Significant mean and peak joint moment and power differences between conditions are illustrated. The peak moment was significantly different between conditions in ankle and hip joints. Right ankle joint power of ABO was greater. ABO group demonstrated greater peak hip power. Figure 1: Trajectories of the (A) COP 1 and (B) COP 2 and (C) Average and (D) peak kinetics parameters (force, moment and power) comparison between barefoot and ABO gait.

CONCLUSION: The purpose of this study was to assess the effects of worn ABO on the hip, knee and ankle kinetic parameters and COP of the foot. The findings of the present paper allowed us to sort out the effects of ABO on gait kinetic parameters and on the shift of the foot COP. Mean ankle power significantly decreased with the ABO due to the ABO limiting the ankle range of motion. An interesting finding was that the peak hip moment increased in the ABO leg. Moreover, the relationship indicated between groups and the shift in the foot COP trajectory suggest the COP of the foot as an important diagnostic tool in the evaluation of gait impairments and progress in gait rehabilitation. ABO cause a shift in the COP that was conducive to knee frontal kinetic modifications which reduced the knee adduction moment. When taking into consideration the proximal and distal kinetic relationships, the present paper also suggests that the modifications in distal sites of the kinetic chain namely the COP of the foot affect or have been affected by proximal sites (hip, knee and hip) moments. This suggestion underscores the benefit of the rehabilitative interventions with ABO. Such interventions will focus on alterations in the location of the COP of the foot (e.g. lateral, medial, posterior and/or anterior shift) which become important indicators of a better redistribution of force and moments on the ankle, knee and hip joints to achieve walking with ABO.

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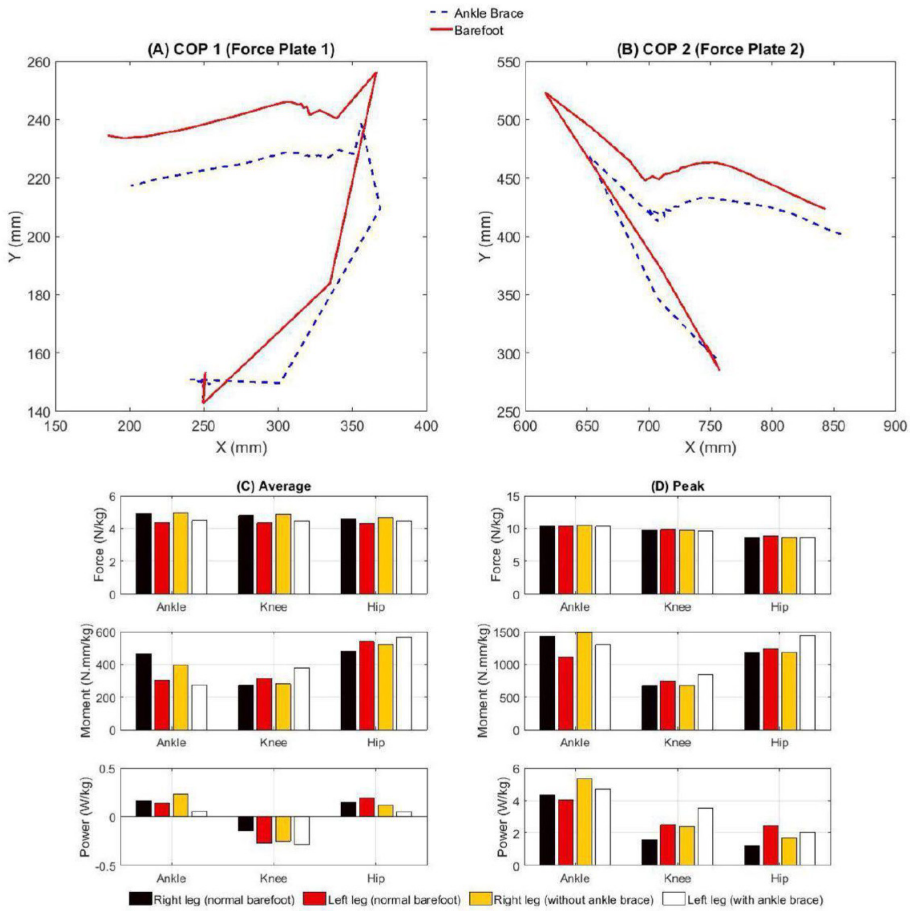
Ankle Brace
Barefoot
(A) COP 1 (Force Plate 1)
(B) COP 2 (Force Plate 2)
Y (mm)
X (mm)
(C) Average
(D) Peak
Force (N/kg)
Moment (N.mm/kg)
Power (W/kg)
Ankle
Knee
Hip
Right leg (normal barefoot)
Left leg (normal barefoot)
Right leg (without ankle brace)
Left leg (with ankle brace)

MODELLING, SIGNAL PROCESSING & SENSING

PIII.12 Recording of EMG activity from tibialis posterior with fine-wire: A protocol

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Background: Tibialis posterior (TP) is the primary invertor of the foot and the main dynamic stabiliser of its medial longitudinal arch (1, 2). To record electromyography (EMG) data from TP, fine-wire electrodes must be used in place of surface electrodes due to muscle depth (~3 cm) (2). Despite previously published fine-wire EMG methods (3, 4) the technique remains challenging and detailed guidelines do not exist. The aim of this work is to outline a comprehensive protocol for fine-wire EMG recording from TP to aid future recordings from this muscle. Equipment: Recordings are performed with bipolar fine-wire electrodes (44 gauge×100 mm paired-hook wires, Teflon-coated stainless-steel wire). Anatomical approach: Needle insertions into TP are performed using the anterior approach (through tibialis anterior) or the posterior approach (halfway between the medial malleolus and the tibial tuberosity, posterior to the medial border of the tibia and angled towards the fibula) (2). The posterior approach is advised for walking studies as the electrode tips often retract through the interosseous membrane into tibialis anterior with the anterior approach (2). Step 1: Ultrasound. From the ultrasound image (B-mode) the depth of TP can be ascertained. The safety window can also be marked by locating the neurovascular bundle and border of the tibia. A broadband transducer enables clear visualisation of superficial (neurovascular bundle) and deep (TP) structures simultaneously. Doppler ultrasound imaging can be useful in locating the neurovascular bundle: a bright blue/red spot indicating blood flow at the site. Step 2: Preparing to insert. Care must be taken to ensure that the uninsulated tips of the needle are pointing in opposite directions before insertion. With the participant's leg flexed and raised off the bed, supported by the knee of the researcher, the needle casing can be placed on the lateral aspect of the leg. This makes it easy to visualise a slice through the leg and the correct angle of insertion, reducing the likelihood of an incorrect insertion into the more superficial flexor digitorum longus. Step 3: Verifying correct electrode location. Successful insertion results in slight inversion of the foot without toe movement with electrical stimulation. Recording data: Experience indicates that degradation of the signal occurs with time. It is thus recommended that recording protocols limit data collection time to ~30-40 minutes. Anecdotal evidence indicates that performing a maximal voluntary contraction (MVC) with TP electrodes is uncomfortable and may therefore also not be a true MVC. Normalising to the peak of the signal is advocated as work in our department found peak normalisation was less variable than MVC normalisation. 1. Rha et al. ARCH PHYS MED REHAB. 2010;91(2):283-7. 2. Semple et al. J FOOT ANKLE RES. 2009;2. 3. Murley et al. J ELECTROMYOGR KINES. 2009;19(2):E69-E77. 4. Murley et al. J FOOT ANKLE RES. 2009;2(1):35.

Figure 1. Preferred position for fine-wire insertion showing a) the shank is raised off the bed and b) the needle casing on the lateral side to visualise a line through the shank

PIII.13 Locally-Time-Warped and Gaussian-Kernel-Weighted MUP Template Estimation

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BACKGROUND AND AIM: Variations in the shapes of the motor unit potentials (MUPs) within a MUP train (MUPT) recorded following a sequence of motor unit (MU) discharges make it difficult to accurately estimate a representative MUP template. MUP shape changes are caused by neuromuscular transmission instability within the MU and contamination from MUPs generated by other active MUs. A common strategy for estimating a MUP template is spike-triggered or ensemble averaging (STA), where the MUPs of a recorded MUPT are arranged as rows within a matrix, and a simple mean is computed down each column. Here an alternative strategy based on local-time warping, where the similarity of values from nearby columns are considered using a Gaussian-kernel to determine the weight with which a specific value contributes to the resulting template instead of having all values in the same columns having an equal weight in determining the MUP templates as with STA is examined. The logic is that local distortion effects, especially of neuromuscular transmission instability, may advance or delay portions of a MUP in one row of the matrix relative to other portions of MUPs in other rows of the matrix. This technique has been used in other signal processing applications.

METHODS: To determine the weight with which a specific value of a specific MUP contributes to the MUP template estimate, fixed-window width localized searches to determine the most similar local point in each of the other MUPs of the train are performed. An accumulated weight across the MUPs of the MUPT is then calculated using a Gaussian kernel based on the discovered similarities. This process is then repeated to estimate each specific value of the resulting MUP template estimate. A series of simulated EMG signals were generated based on 3 different muscles, activated at 5 different force levels. These levels of activation provided EMG signals with an [8-182] MUP firings per second range of intensities (MUPs with a minimum of 1.25 kV/s^2 each). In addition, for each level of activation, EMG signals were generated whose MUPs had jitter variances of 0, 25, 50 and 100 ?s, respectively. The simulated EMG data, with accompanying gold standard information regarding firing time and true MUP template shape, was used to compare the locally-time warped and Gaussian kernel weighted (LTW-GKW) strategy to STA. The spike duration of each gold-standard MUP template was computed, and RMS values calculated using the differences between the gold standard and estimated templates within (MUP RMS) and without (baseline RMS) the spike duration were computed.

RESULTS: A significant improvement over STA was observed ($p < 1e-16$) with respect to both MUP and baseline RMS (by a median factor of 3.4). Analysis using ANOVA does not indicate any significant relationship with jitter value ($p > .9$) for either MUP or baseline RMS.

CONCLUSION: Mean residual RMS and RMS variability were lower and less affected by intensity for LTW-GKW.

PIII.14 Square Drawing Test for Motor Capacity Modeling in Post-Stroke Individuals

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BACKGROUND: Ordinal clinical scales are conventionally used for the assessment of the upper limb motor functions and for predicting the course of regaining motor capacity. Although validated and standardized, these scales require significant time to be conducted and may lack objectivity and reproducibility due to human factor. Automated robotic methods for functional assessment offer fast, objective and consistent alternative.

METHODS: The objective of this study was to examine the relationship between a square drawing test (DT) and the score on the shoulder-elbow tasks of the Wolf Motor Function Test (WMFT). Forty seven subacute stroke patients who participated in the study were tested before and after the four week rehabilitation program. The drawing test was performed using a mechanical manipulandum and a digitizing board. The task involved drawing a square within the predefined template by pushing/pulling the handle of the manipulandum in the horizontal plane. The drawing test performance was represented by normalized area within the square template, computed as a ratio of area within outer square template and the area of outer square template. The 17-item WMFT was performed, but only seven tasks including shoulder-elbow movements were taken into consideration. The sum of scores for the selected tasks, ranging from 0 to 35, was the WMFT outcome measure.

RESULTS: Both clinical and square drawing based measures showed statistically significant improvement after four weeks of rehabilitation. The normalized DT area increased from 0.69 ± 0.21 to 0.73 ± 0.18 ($p = 0.0156$), while the WMFT score improved from 21.7 ± 6.0 to 25.9 ± 6.5 ($p < 0.001$). Pearson's correlation coefficient values showed statistically significant correlation between the Drawing Test and WMFT, before ($r = 0.73$, $p < 0.001$) and after ($r = 0.76$, $p < 0.001$) the rehabilitation.

CONCLUSION: The results show that the Drawing Test is sensitive to upper limb motor functions improvement and strongly correlates to the WMFT score. Therefore, the method can be successfully applied in the clinical setting for fast, simple and precise evaluation of post-stroke individuals.

PIII.15 A Mathematical Model of Action Potential Propagation, Force Production, and Fatigue in Skeletal Muscle Fibres

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BACKGROUND AND AIM: Despite the extensive research that has gone into uncovering the cellular mechanisms of fatigue, the mechanisms of action of the various contributory components and their interactions have yet to be fully established. The many interdependent electrical and metabolic factors contributing to muscular fatigue include accumulation of extracellular potassium ions and decreased levels of ATP, accompanied by reduced muscle fibre excitability and impaired calcium uptake from the sarcoplasmic reticulum (SR). Computational models of excitation-contraction coupling (ECC), the signalling cascade controlling muscle contraction and relaxation, can provide a valuable means of solidifying the specific contribution of each factor contributing to the fatigue process, assuming the underlying model structure is sufficiently physiological.

METHODS: A mathematical model of ECC in skeletal muscle has been developed that incorporates feedback from muscle relaxation dynamics in estimating membrane excitability and force generating capacity in both fast and slow twitch muscle fibres at a range of physiological temperatures. The DHPR voltage sensor, responsible for initiating SR calcium release, is modelled as a low-conductance L-type calcium channel with a calcium-dependent inactivation gating mechanism and a dynamic Nernst potential tracking changes in both intracellular and extracellular calcium. Both the Na+/K+-ATPase and SR Ca2+-ATPase are modelled as ATP dependent ionic pumps, contributing to action potential repolarization and calcium uptake into the SR, respectively. A compartmental modelling approach was adopted wherein both fibres were split longitudinally into equally sized compartments of 100 um, each containing a transverse-tubular system modelled as a radial cable with 20 concentric compartments. A stimulus was introduced at the middle of each fibre to elicit a bidirectional propagating action potential, initiating ECC within each compartment. Changes in transmembrane potential were calculated using the cable equation, resulting in a distribution of force responses along the muscle fibre.

RESULTS: Preliminary results simulating 5 Hz stimulation for 5 seconds in both fast and slow twitch fibres showed a reduction in force accompanied by decreased calcium uptake into the SR, reduced levels of ATP, and increased resting membrane potential over time. When incorporating feedback from ATP levels on the ionic pumps and calcium levels on the voltage sensor, these effects were even more pronounced, complementing experimental results. Furthermore, it was also observed that increasing extracellular calcium in fatigued muscle fibres helped repolarize the action potential and lower potassium accumulation within the transverse tubular system, an effect that has previously been shown experimentally.

CONCLUSIONS: This is the first computational model of ECC in skeletal muscle to date to incorporate the effects of ATP-dependent ionic pumps, changes in the transsarcolemmal calcium gradient, and calcium-dependent inactivation of the DHPR voltage sensor on both the propagating action potential and the whole fibre force response. While the effects of these dependencies may be negligible during an isometric twitch, they have been demonstrated experimentally to contribute more actively during long trains and higher frequency stimulation, as well as in diseased muscle fibres, allowing for deeper investigation into the cellular mechanisms of fatigue.

PIII.16 Influence of electrode locations for evaluation of muscular fatigue on biceps brachii muscle

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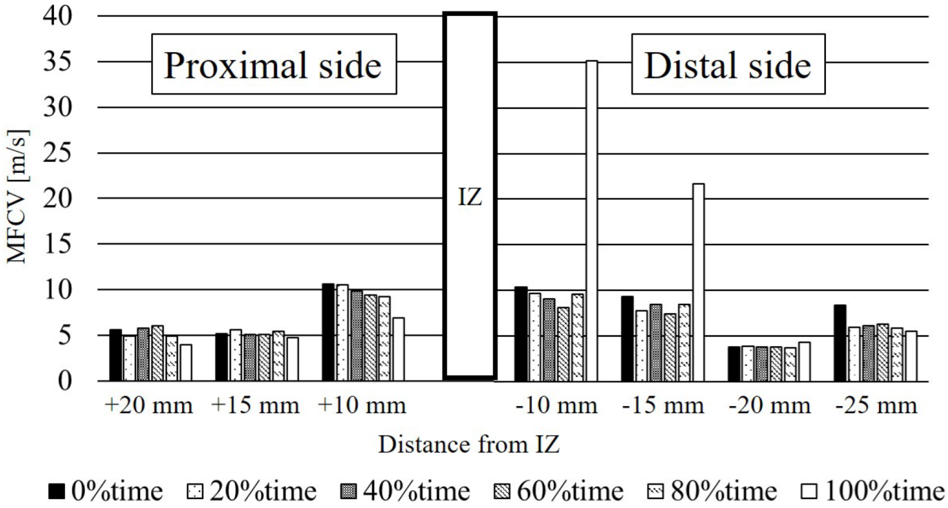
BACKGROUND AND AIM: The surface Electromyogram (sEMG) is one of the method of evaluation of muscle function objectively and noninvasively. The paper by L. Mesin et al. (2009) reported that muscle fiber conduction velocity (MFCV), and root mean square of an amplitude (RMS) are different in innervation zone (IZ) position and another, and it is important to evaluate avoiding IZ position. However, it has not been clarified that difference in the relative positions of IZ and electrode during a muscle fatigue. In this study, the purpose was to clarify difference of electrode location during a muscle fatigue in a biceps brachii muscle.

METHODS: Four healthy subjects were seated in chair, and sustained the right arm joint angle at 90 degrees until their exhaustion during 40% of maximum voluntary contraction (MVC). sEMG was recorded from the right biceps brachii muscle, and using electrode array was composed of eleven silver wires with diameter of 1 mm and a length of 10 mm, and attached on the muscle belly. The distance between neighboring electrodes was 5 mm. Ten signals were derived bipolarly from paired neighboring wires filtered by band-pass from 5 Hz to 1 kHz, and were digitized with sampling frequency of 10 kHz. In the data, the duration was divided into eleven equal parts, and the signals which were 0.4 seconds at beginning each part were analyzed. In data analysis, Cross correlation coefficients (CC) with adjacent channel were calculated each 40 ms were calculated, and MFCV were determined. In addition, IZ position was estimated by visual analysis of the signals.

RESULTS: In IZ position, CC were lower than other locations, and MFCV were higher than other channels in spite of the muscle fatigue. To compare electrode locations, the means of MFCV which CC ware not lower than 0.8 were calculated. Figure shows the changes of MFCV in electrode positions at subject A. In electrode location where is the proximal side than IZ position, MFCV showed trending to decrease with the muscle fatigue. However, MFCV were not decreased in the distal side than IZ position at three subjects. In this location, MFCV was higher than previous index (3 ~ 8 m/s). Masuda et al. (1991) reported that the distribution of IZ positions are normally located from muscle belly to distal side in biceps brachii muscle. Therefore, the results suggested that other motor units activated with the muscle fatigue, and new IZ where is located distal side was made. From the above, it is better to evaluate at the proximal side than IZ position which there are at fatigue initial in the muscle fatigue.

CONCLUSIONS: In this study, the purpose was to clarify difference of electrode location during a muscle fatigue in a biceps brachii muscle. As the results, MFCV showed different values with the proximal side than IZ position and the distal side. This suggested that other motor units activated with the muscle fatigue, and new IZ where is located distal side was made.


Proximal side
Distal side
IZ
MFCV [m/s]
0
5
10
15
20
25
30
35
40
+20 mm
+15 mm
+10 mm
-10 mm
-15 mm
-20 mm
-25 mm
Distance from IZ
0%time
20%time
40%time
60%time
80%time
100%time

MOTOR CONTROL

PIII.17 The effects of exercise-induced fatigue and eccentric muscle damage on kinesthesia

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BACKGROUND AND AIM: Our ability to sense the position and movement of our limbs, or kinesthesia, relies on a combination of a centrally-derived sense of effort as well as peripherally-derived afferent information. One class of these afferent receptors, the muscle spindles, can be stimulated by mechanical muscle vibration which has been shown to disrupt kinesthesia. Exercise-induced muscle fatigue has also been shown to impair kinesthesia. Impairment persists if the exercise involves lengthening contractions that induces eccentric muscle damage. It remains unclear exactly how or where this disruption occurs and whether muscle spindles are implicated in the disruption of kinesthesia with fatigue.

METHODS: In Exp. 1, we used a movement task in which subjects (n=10) performed a slow (22 deg/s) eccentric extension of the right elbow through the horizontal plane without vision of the arm. During elbow extension, subjects opened the initially closed thumb and index finger of their right hand when they judged it to be passing through a specified target position. The eccentric movements were performed against a load equal to 10% of each subject's flexion MVC. Task accuracy was defined as the elbow angle at which subjects opened their hand relative to the target. We investigated performance under conditions with and without mechanical vibration of the eccentrically-active biceps, as well as before and after an eccentrically-based exercise protocol that induced fatigue in the biceps. In Exp. 2, we used the same exercise protocol and examined performance of the same task under passive conditions. A motor and pulley system was used to move the subject's (n=8) limb passively through extension, removing the need to perform the task eccentrically against a load. During this passive extension task, we again compared conditions with and without vibration of the lengthening but quiet biceps, and before and after eccentric exercise.

RESULTS: In Exp. 1, muscle vibration of the eccentrically-active biceps resulted in subjects opening their hand short of the target compared to without vibration. Similarly, eccentric exercise also independently disrupted kinesthesia and task performance. After eccentric exercise, subjects undershot the target more than before exercise. Exercise did not have a significant influence on the effects of vibration. Subjects continued to undershoot the target more when the biceps were vibrated, just as they had done before the fatiguing exercise. In Exp. 2, muscle vibration again resulted in greater undershooting of the target compared to without vibration, both before and after exercise. In contrast, subjects now performed with similar accuracy before and after exercise. Thus, the passive task eliminated the effects of exercise we observed in Exp. 1.

CONCLUSIONS: Our results suggest that the CNS continues to rely heavily on muscle spindles for kinesthesia, even when they reside in a muscle exposed to fatiguing eccentric contractions.

PIII.18 The effects of intermittent blocking of visual information on walking in elderly persons

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BACKGROUND AND AIM: Visual information is important for the stability of walking in elderly persons; however, it is unclear which walking parameters it affects. Therefore, the purpose of the present study was to intermittently block visual information during walking and to investigate the difference according to age.

METHODS: The subjects were divided into two groups. One group comprised 20 young adults (mean age: 21.7 ± 0.8 years) and the other group comprised 20 elderly persons (71.5 ± 4.2 years). Visual information was blocked intermittently at a frequency of 10 Hz by using liquid-crystal shutter goggles (manufactured by Visionup). We set three conditions: no goggles, with goggles at a duty ratio of 30%, and with goggles at a duty ratio of 70%. The subjects were asked to walk on an 8-shaped walking path (20 m, one lap) for 10 min at a comfortable walking pace. We evaluated the scaling index (α) of the stride interval, walking speed, cadence, and step length. The scaling index α represents the long-term correlation of the stride interval.

RESULTS: The scaling index α of elderly persons was significantly lower than that of young adults under the three conditions. Furthermore, the step length of elderly persons significantly decreased compared with that of young adults at a duty ratio of 70%. There was no significant difference in the evaluated walking parameters within the groups due to the blocking condition of visual information.

CONCLUSIONS: When blocking visual information in elderly persons, the long-term correlation of walking is maintained but the step length is affected when visual information is blocked at a duty ratio of 70%. Therefore, the step length is considered a useful indicator that acutely responds to intermittent blocking of visual information.

PIII.19 Change of EMG and MMG amplitude on human vastus medial muscle with aging

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BACKGROUND AND AIM: A decrease of lower muscles due to aging is associated with disuse muscle atrophy. The aim of this study is to elucidate the difference of muscular activity by aging with the use of electromyogram (EMG) and mechanomyogram (MMG).

METHODS: The subjects were 117 healthy female and male volunteers 22-79 years of age, and they provided a written informed consent to participate in this study after a detailed explanation including the purpose and procedures of the experiment. The subject was seated in a chair and knee joint angle of dominant foot was fixed at 90-degrees, and maintained an isometric contraction force of 20%, 40% and 60% of the maximum voluntary contraction (MVC) for 5 seconds. EMG and MMG were measured by an electrode arrays (inter-electrode distance of 5 mm) and 3-axis accelerometer (weight of 4.4g), respectively. EMG, MMG and force signals were stored on a personal computer through an A/D converter with a 16-bit resolution and with a sampling frequency of 1 kHz. The root mean square (RMS) value was calculated by using time 2-seconds of EMG and MMG. In each contraction force, Peason's correlation coefficient (r) was used to study the relationship between each parameter and age.

RESULTS: Maximum voluntary contraction (MVC) of knee extension was decreased depending on age and showed negative moderate correlation (male：$r=-0.517$, $p<0.01$, female：$r=-0.504$, $p<0.01$). Relation between RMS of EMG and MMG and age on each contraction force were shown in Table 1. Correlation coefficient values in both EMG and MMG was decreased depending on age and showed negative low correlation at 40 and 60% MVC.

CONCLUSIONS: In 40 and 60% MVC, the RMS of EMG and MMG were decreased depending on age. Therefore, the reduction of RMS of EMG and MMG at 40% and 60% MVC due to aging might reflect the atrophy of fast twitch muscle fiber.

Table 1: Relationship between RMS of EMG and MMG values and age

Contraction force (%MVC)	Correlation coefficient			
	EMG		MMG	
	Male	Female	Male	Female
20	-0.145 (ns)	-0.253 (*)	-0.225 (ns)	-0.490 (**)
40	-0.320 (**)	-0.392 (**)	-0.515 (**)	-0.444 (**)
60	-0.356 (**)	-0.454 (**)	-0.509 (**)	-0.495 (**)

ns: no significant, *: p<0.05, **: p<0.01

PIII.20 Beta late than never: Beta rhythm suppression during action observation is sensitive to somatosensory experience in an object manipulation task

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BACKGROUND AND AIM: Rhythmic neural activity over sensorimotor brain regions within the alpha (8-13 Hz) and beta bands (14-22 Hz) is modulated when an observer views another person's actions. This sensorimotor activity is sensitive to the observer's experience with the observed action, as well as recent sensorimotor experience with the observed object (i.e., in an object grasp-and-lift task). However, little is known about the relationship between skilled motor performance and alpha/beta band activity as a function of self-experience. This study used EEG to answer the following: 1) Do different types and amounts of sensorimotor experience with objects differentially alter alpha and beta band event-related desynchronization (ERD) during observation of similar actions? 2) Do differences in alpha or beta activity correlate with skilled motor performance?

METHODS: Participants (N = 140) watched a 10-minute video showing an actor lifting objects with which they had varying levels of sensorimotor experience: a toothpaste tube (Common), a brass block (Familiar), or a yellow plastic block of unusual density (Novel). Next, participants gained experience by performing 300 lifts with the same objects (Extensive) or two lifts with the same object and 298 lifts of distractor objects (Brief). Participants then viewed the same 10-minute video. Thus, participants were assigned to 1 of 6 groups: 1) Common Extensive; 2) Common Brief; 3) Familiar Extensive; 4) Familiar Brief; 5) Novel Extensive; or 6) Novel Brief. Alpha and beta activity over C3 was analyzed for baseline and post-lifting video action observation. Motor performance was assessed through an analysis of load phase duration (duration of force increase between object contact and lift-off).

RESULTS: At baseline, there was greater beta suppression for the Common object compared to the Novel object. Post-task, an Object x Experience interaction was found; for those in the Extensive experience group, there was more beta suppression for the Common object compared to the Novel object. Recent experience only affected beta suppression for those in the Novel object condition, with increased beta suppression for Brief compared to Extensive groups. There was no significant effect of object or experience on alpha activity. An analysis of lifting kinematics revealed the most efficient lifts were observed for Common objects, followed by Familiar, and then Novel objects. Post-task beta band suppression was correlated with load phase duration for the Novel Extensive group, indicating increased beta suppression was associated with less efficient lifts for this group.

CONCLUSIONS: Together, these results suggest that increased beta suppression does not correspond with skilled motor performance. Beta activity may reflect a particular sensitivity and attentional bias to the somatosensory aspects of novel objects in an object lifting task, in addition to neuronal processing efficacy.

PIII.21 Mixed nerve silent period evoked from Opponens pollicis muscle during a precision motor task with the isometric contraction of the ipsilateral knee extension

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Background and Aim: The mixed nerve silent period (SP) is defined as the electrical inactivity, which is a transient suppression of muscle activation, produced by electric stimulation to the innervating nerve during continued muscle effort (Kimura, 2001). This period results from several physiological mechanisms. In this study, to clarify the excitability of the central nervous system function via a difference in the feedback method during motor task of lower extremity, we examined the alterations in the duration of SP recorded from the opponens pollicis muscle during a precision motor task. This task involved isometric knee extension using visual feedback and verbal conduction.

METHODS: 12 healthy adults (7 males and 5 females; mean age: 23.7 ± 2.1 years) participated in this study. SP was recorded from the opponens pollicis muscle during a precision motor task involving with isometric contraction during ipsilateral knee extension with constant torque by two kinds of feedback. The precision motor task was carried out as follows; Subjects maintained knee extension torque at a constant strength using the BIODEX SYSTEM 3 with 60° of knee flexion. The knee extension torque was set at 25% of individual maximum effort. We monitored the torque using two methods. The first method used subjects' own visual feedback with gazing at the BIODEX screen (Task A). The second task featured torque adjustment by the examiner's verbal instruction. Subjects' eyes were bandaged to eliminate visual feedback (Task B). SP was recorded from the opponens pollicis muscle while subjects maintained ipsilateral isometric knee extension during an A-B-A task order. As a stimulus condition, a constant current rectangular wave with a frequency of 0.5 Hz and a duration of 0.2 ms, was added 16 times in the median nerve at the wrist with the intensity of supra-maximum, which maximal M wave was evoked. We compared the duration of SP between tasks in each dominant and non-dominant side.

RESULTS: The duration of SP on the dominant leg was 109.1 ± 5.2 ms (Task A), 105.2 ± 7.2 ms (Task B), and 107.6 ± 6.7 ms (Task A). And that on the non-dominant leg was 111.3 ± 6.1 ms (Task A), 105.9 ± 4.4 ms (Task B), and 109.3 ± 4.4 ms (Task A). There was no significant difference on the dominant leg side. However, during Task B on the non-dominant leg side, the duration of SP was shortened (Tukey's test, p = 0.01, 0.08).

CONCLUSIONs: During less-skilled motor adjustment using the non-dominant leg, the motor control with verbal conduction and no visual feedback requires more afferent activation. In these cases, central nervous system function excitability associated with ipsilateral upper extremity increases, even if the task involves the lower extremity.

PIII.22 Opponens pollicis long latency reflex during the ipsilateral sustained knee torque maintenance.

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Objective: In the rehabilitation process for the return to play after sports injury, there is the case who sports activity cannot be acquired smoothly despite no problem in physical findings such as muscular strength, range of joint motion, performance battery test and so on. On the other hand, some people can smoothly return to competition despite the insufficient physical findings. As a preliminary study to clarify the excitability of central nervous system function during motor control, the aspect of long latency reflex in the upper limbs, which is an indicator of excitability of upper central nervous system function, while maintaining knee extension torque with constant strength.

METHODS: Subjects were 10 healthy adults (5 males and 5 females) who did not show any abnormality in the neurological function and musculoskeletal system. Prior to the experiment, all of the subjects were informed the purpose of this study based on the descriptions, and their agreement for participation was obtained from all of the subjects. Long latency reflex was recorded from opponens pollicis muscle during the ipsilateral sustained torque demonstration of the knee extension using the BIODEX SYSTEM 3 (Biodex medical system, inc.) by different feedback methods in healthy subjects with maintaining the 25% of individual peak torque by the visual feedback and the verbal instruction. In order to evoke the long latency reflex, sustained contraction of the recording muscle is needed. So, in this experiment, as the contraction condition, we chose to gently hold the rubber ball. From the acquired waveform, the appearance characteristic of long latency reflex between each task was visually examined.

RESULTS: In 8 out of 10 subjects, the aspect of the long latency reflex was changed according to the difference in task.

Discussion and Conclusion: In this study, the late components of long latency reflex increased in non-dominant side in Task B in 8 out of 10 subjects. In the occasion of hypothesis that Task B was more difficult, and much proprioception was activated than Task A, even if it was a motor task of lower extremity, if the difficulty level became higher, it was possible that the excitability of the cerebral cortex related to the upper limb might increase. Therefore, it was suggested that excitability of higher level of cortex might be enhanced if the degree of difficulty becomes higher even if motion control of lower limbs. In the requirement of fine adjustment of motor control, even if the task of lower extremity, it was suggested that the excitability of the cerebral cortex function associated with the upper limb might increase. Because it is not possible to refer to the individual difficulty level of tasks and the skill of lower limbs for each subject in this experiment, follow-up study is needed under the clear conditions of the task, especially individual difficulty and skill.

PIII.23 Effects of sharing goals with others on sense of agency and perceptual motor learning

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BACKGROUND AND AIM: Main purpose of rehabilitation for motor disorders is motor learning (ML), which once again causes the lost motor function to be reacquired. The sense of self-agency (SoA) refers to the feeling of controlling an external event through one's own action. (Gallagher, 2000). Under basic principle of neurorehabilitation based on scientific evidence, the induction of SoA is considered to be important in the process of reacquiring newly movement (Nielsen, 2015). Additionally, interaction with other people such as goal sharing (GS) reportedly enhances rehabilitation effect. We hypothesized that GS would increase SoA, and hence promoted ML. We created an original intentional binding (IB) task to measure SoA and perceptual motor learning and examine our hypothesis.

Methods: Thirty healthy same-gender pairs participated in the study. Fifteen pairs were placed into the GS group (10 males, 20 females ,mean age 20.5 ± 1.4), and other fifteen pairs were grouped into the no-GS group (10 males, 20 females ,mean age 20.4 ± 1.4). Both the GS and no-GS groups were asked to repeatedly stop an object moving in the horizontal direction on a PC display, using the press of a key at the instant when the object arrived at the center of the screen (18 trials × 10 block). The task score was calculated using data describing the distance between the stopped object and the center of the screen. In the GS group, the total scores for each pair of participants were calculated and displayed on the screen, while only the individual scores were displayed in the no-GS group. A beep was sounded several hundred ms after the object was stopped with the key press. The participants estimated the time interval from the key press to the beep (Self-binding), and this estimated time was taken as a surrogate maker of SoA. The short perception between key press and sound indicates the induction of SoA (Moore ,2012). And the participants estimated the time interval between the partner's key press and sound (Other-binding). The short perception between key press and sound indicates the induction of intention to others' action (Poonian, 2013).

RESULTS: The present study demonstrated that SoA and motor performance had higher values in the GS group than no-GS group ($p < 0.01$). As a result of structural equation modeling, induction of intention to others induced SoA, and the SoA influences ML effect.

CONCLUSIONS: Processes including GS with others are important for the improvement of perceptual motor learning.

PIII.24 Forearm muscle synergies during ramp-and-hold gripping in individuals with chronic elbow pain

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BACKGROUND AND AIM: It is largely unknown how the CNS regulates multiple muscle systems in in the upper limb in the presence of pain. This study investigated spatiotemporal activation patterns of forearm muscle synergies during ramp-and-hold gripping performed by 11 individuals with chronic elbow pain and 11 healthy age-matched controls.

METHODS: Presence of elbow pain was confirmed using standard clinical tests, pain threshold and ultrasound diagnostic measures. Surface electromyography was obtained from six forearm muscles when participants randomly performed ramp-and-hold gripping to 15% MVC at three different wrist postures. Non-negative matrix factorization was used to extract the forearm muscle synergies from the time-normalized EMG's.

RESULTS: Dimensionality analyses revealed between group differences in number of muscle synergies, where the elbow pain group had a fewer number of synergies during the ramp phase of gripping and increased number of synergies during the isometric phase of gripping. Further analyses of the spatiotemporal features of forearm muscle synergies showed 1) increased similarity in spatial activation patterns, 2) increased co-contraction of forearm flexors, 3) greater activation magnitude of muscle weightings, and 4) delayed timing of peak activation during ramp phase of gripping in individuals with elbow pain. During the isometric gripping the pain group had lower activation magnitude of muscle weightings.

CONCLUSIONS: These findings indicate that people with chronic elbow pain exhibit a less complex neural strategy for the development of pain-free grip force, which manifests as more similar and simultaneous patterns of forearm muscle activation. In contrast, when maintaining an isometric grip force individual with pain exhibit a more complex neural strategy where a redistribution of muscle activation occurred across synergistic muscles.

PIII.25 Effects of Self-determined choice on motor skill learning and retention

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AIM: Motivation to voluntarily engage in a task for the pleasure is important to facilitate motor skill learning. Recent studies have documented that self-determined choice does indeed enhance intrinsic motivation and performance. However, it has not been clarified for motor skill learning. The purpose of this study was to clarify effects of self-determined choice on the motor skill learning and retention compared to forced-choice in healthy people.

Methods: Eighteen healthy subjects (28 men and 52 women, mean age: 21.6) participated in this study. The subjects were randomly assigned to Forced-choice (FC) group and Self-determined-choice (SC) group. The motor skill task was to rotate two balls by the non-dominant hand. Subjects performed the two-ball rotation task by non-dominant hand in sitting position with supported an elbow on a table. Two balls, each 4.2 cm in diameter and weighted 430 g, were placed on non-dominate palm. Participants rotated the two balls in a clockwise direction as fast as possible for 10 times. First, all subjects performed the task in the baseline trial. And they performed the first, second trial followed by practice session for 1 minutes and retention trial (24h later after third trial). Subjects in the FC group practiced for each practice session with balls which were made to choose among 9 types of designs by the experimenter. Subjects in the SC group practiced with balls which they chose among 9 types of designs by themselves. The time required for 10 rotations on the task (Time for task; seconds) were measured at each trial. Degree of the pleasure during practicing the task was measured using Visual Analogue Scale (VAS;0- no pleasure, 100- greatest pleasure). The time for task in 3 trials; these were analyzed using the repeated two-way analysis of variance (trial × group) and Post hoc task (within each group). VAS for pleasure were analyzed using unpaired t-test.

RESULTS: Both groups showed a significant reduction in the time for task between the first trial and 2nd, 3rd trial, but there was on interactions with each group. In the FC group, there were significant reduction in time for task over 2nd and 3rd trial as compared to the first trial ($p<0.01$). However, the SC group showed significant differences between all trails ($p<0.05$). Score of VAS for pleasure was no significant differences between FC and SC groups ($p=0.21$). But score of VAS in the SC group were greater than FC group.

CONCLUSION: Our results suggest that self-determined choice produces motivation to voluntarily engage in a task for the pleasure and improves the motor skill learning and retention effect compared to forced-choice condition.

PIII.26 Shared common input to hand muscles during a two-degrees of freedom force task reveals muscle synergies

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BACKGROUND AND AIM: It has been hypothesized that the central nervous system optimizes the control of different muscles by sending common neural signals to the recruited muscles for a given action. However, the evidence for this coordinated activity is scarce. Recent data from recordings of populations of motor neurons innervating agonist muscles acting on one degree of freedom showed that most of the neural oscillatory inputs sent to muscles is shared [Laine et al. 2015]. However, the muscles studied shared the same function (i.e., knee extension), or performed a synchronous modulation of force (i.e., sinusoidal contractions). Therefore, the neural connectivity found in these tasks may be dependent on other factors rather than a central coordination. Here we aim at verifying if this connectivity persists when hand muscles perform a two-degrees of freedom movement task with an uncorrelated force biofeedback. In this task the two degrees of freedom can be biomechanically controlled independently.

METHODS: Ten youth healthy subjects (six men) participated in the experiment and performed simultaneous steady contractions of index abduction and thumb flexion at either 2.5% and 10% of the maximal force (MVC). The two tasks were performed individually (other finger not producing force) or simultaneously (other finger active at 2.5% or 10%MVC). Subjects performed two trials of 60 s steady contractions in each of the eight conditions. The visual feedback was presented as a cursor whose horizontal and vertical positions depended on the force exerted by the thumb and index finger, respectively. The myoelectrical activity from the first dorsal interosseous and thenar muscles was recorded with high-density surface EMG. Motor unit spike trains were identified with a decomposition algorithm. Subsequently, the low-frequency component of the neural drive to the two muscles was estimated by low-pass filtering the cumulative sum of discharges of the identified motor units. Similarities in the force and neural drive across digits were assessed by computing the cross-correlation coefficient.

RESULTS: For the simultaneous contractions, the mean cross-correlation coefficients of force and neural drive were 0.30 ± 0.06 and 0.41 ± 0.03, respectively ($t(102399) = 100.62$ and $t(102399) = 143.85$, both with $p<0.001$). The highest correlation for both force and neural drive occurred when both fingers were contracting at 10%MVC, with a coefficient of 0.39 ± 0.08 and 0.48 ± 0.07, respectively.

CONCLUSIONS: These results reveal for the first time a shared common input to motor neurons of muscles acting in a two degrees of freedom force task. We interpret the present results as a functional mechanism accomplished by the central nervous system to coordinate digit forces. Laine CM, Martinez-Valdes E, Falla D, et al (2015) Motor Neuron Pools of Synergistic Thigh Muscles Share Most of Their Synaptic Input. J Neurosci 35:12207-12216. doi: 10.1523/JNEUROSCI.0240-15.2015

PIII.27 EMG activity and function of abductor hallucis during fatigue and postural sway

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BACKGROUND AND AIM: Abductor hallucis (AH) is a large intrinsic foot muscle and its activation results in abduction and flexion about the first metatarsophalangeal joint. AH may also play a key role in postural control due to its support of the medial longitudinal arch of the foot. Although previous work has shown that fatigue can influence function of AH and decrease arch support of the foot, the effect of fatigue in AH on postural sway is not clear. Thus, the aim of this study was to examine the neuromuscular control of AH before and after a sustained submaximal fatiguing contraction, and to quantify the influence of fatigue on postural sway.

METHODS: 13 subjects (26.4 ± 4.3 years) performed an isometric abduction task by pressing with the medial side of their right hallux onto an L shaped metal platform that was rigidly attached to a force sensor. High-density surface EMG was collected from AH using a 64-channel electrode matrix in bipolar mode, resulting in 59 bipolar recordings along the length of the array. Each subject performed maximal voluntary contractions (MVCs) before and immediately after a 50% MVC contraction held until task failure (defined as the time when force magnitude dropped below 45% MVC force for 5 s). Postural sway was evaluated during quiet single leg standing before and after the fatiguing contraction and quantified as the mean velocity and the RMS of the center of pressure (COP) in both the mediolateral and anteroposterior direction. EMG channels were rectified and normalized to EMG amplitude during the pre-fatigue MVC trial and data from all clean EMG channels of the array were averaged. Also, a cross-correlation function was used to examine the relationship between EMG amplitude and excursions of the COP in the mediolateral and anteroposterior directions after both signals were low-pass filtered at 5 Hz.

RESULTS: There was a 16.4% decrease in MVC force ($p < .001$) and a 29.6% reduction in EMG amplitude during MVCs ($p < .001$) after the fatiguing contraction. There was a 14.8 ± 6.1% increase in the RMS of the COP in the mediolateral direction during the postural sway task ($p = .039$) after the fatiguing contraction. In addition, the mean correlation between EMG and COP in the mediolateral direction during single leg stance was $r = 0.65 \pm 0.08$ before the sustained contraction, however this value decreased ($p = .001$) to $r = 0.47 \pm 0.10$ after the fatiguing contraction. All other results were not significant ($p > .05$).

CONCLUSIONS: Our results suggest an impaired ability of AH to support postural control after sustained fatiguing contractions, highlighting the important role of AH to control and stabilize the foot to maintain balance in the mediolateral direction. In addition, novel aspects of the current study included the use of multi-channel EMG to assess muscle activity in AH across motor control tasks and the use of an isometric force task that emphasizes intrinsic foot muscle function.

PIII.28 Sub-sensory electrical stimulation modifies response to haptic perturbations during walking in a clinical exoskeleton

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INTRODUCTION: One of the goals of robot-assisted gait therapy is to provide patients with the proprioceptive information regarding the correct execution of a desired walking trajectory. Nevertheless, motor-impairments caused by neurological disorders such as stroke are often associated with proprioceptive deficits. Recently, mechanical and electrical sub-sensory stimulation applied to mechanoreceptors in the limbs has been proposed as a mean for improving proprioceptive ability in intact and impaired individuals, during simple and complex tasks. This stimulation is supposed to increase the depolarization of the proprioceptive organs in the limbs thus making them more sensitive.
METHODS: Here we tested the use of sub-sensory electrical stimulation targeting muscle spindles to improve the response of 30 healthy individuals to robot-induced perturbations while walking in an exoskeleton for robot-assisted gait training. Subjects performed two motor adaptation experiments where they adapted to perturbations driving a longer step length. The motor adaptation experiments were performed while walking attached to the Lokomat device, that is the most commonly used robot for gait rehabilitation. The Lokomat was back-driven for 80 steps (baseline phase), allowing the subjects to walk normally, then a velocity-dependent perturbation increasing step length by 20% was applied for 80 steps (force-field phase) and finally subjects performed another bout of 80 steps without perturbation (after-effect phase). Each subject performed one experiment with and one without sub-sensory electrical stimulation applied to their hamstring muscles, in a randomized order. Stimulation was applied as white Gaussian noise current with RMS equal to 90% the sensory threshold of each subject (calculated as 191.3 ± 144.8 mA through all the experiments of all the subjects). During each experiment (STIM and SHAM) subjects were effectively blind regarding the stimulation condition.

RESULTS AND DISCUSSION: In our analysis we found two distinct behaviors in the adaptation plots for the STIM and SHAM conditions. Specifically, in the Force-field phase, we observed exponential changes in step length that converged faster and towards a higher target step length in the STIM condition with respect to the SHAM condition. These observations suggest that subjects, during the STIM condition, adapted faster but to a less extent with respect to the SHAM condition. The in deep analysis of the exponential fittings and of the step length data supported these observations. Our results suggest an effect of the stimulation leading to an increased excitability of muscle spindles. This increased excitability expresses in both a faster adaptation, as more information is timely transmitted to the brain, and a bigger kinematical error, as increased excitability leads to an offset in the sensed forces and positions.

PIII.29 Bilateral Deficit in Human Upper Body Muscles

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BACKGROUND AND AIM: Bilateral deficit (BLD) describes a phenomenon that the force produced during simultaneous (bilateral) maximal contraction of both limbs is lower than the sum of the forces produced by the left and right limbs separately. The aim of this investigation was to examine potential sex difference in bilateral deficit for human elbow flexor (EF) and finger abductor (FA) muscles.

METHODS: Eighteen young healthy subjects (eight women) participated in this 3-visit investigation. After the familiarization visit, the examinations of isometric elbow flexion at the 90-degree joint angle and index finger abduction were conducted in a randomized order for the next two separate experimental visits. During each experimental visit, the maximal isometric strength testing of the designated muscle group was performed on the unilateral left (UL), unilateral right (UR), and bilateral conditions with a randomized order. Surface electromyographic (EMG) signals were recorded during each isometric strength testing to examine the muscle activation of the biceps brachii and first dorsal interosseous (FDI). The bilateral index BI(%) was calculated as 100 × [bilateral / (UL + UR)-100], with a negative percentage indicating the presence of BLD. Separate two-way (condition [UL+UR vs. bilateral] × sex [men vs. women]) mixed factorial analyses of variance (ANOVAs) were used to examine if the isometric force values differed between two conditions for both sexes. For each side of the designated muscle (e.g., right FDI), separate two-way (condition [unilateral vs. bilateral] × sex [men vs. women]) mixed factorial ANOVAs were performed to examine the EMG amplitude between two conditions for both sexes. The alpha level was set at $p \leq 05$.

RESULTS: All men demonstrated positive BLD for both EF and FA exercises. For women, one and five subjects did not demonstrate positive BLD for EF and FA, respectively. There was a significant two-way interaction ($p = 0.043$) for the EF exercise. The follow-up paired samples t-tests indicated that the isometric force values of the bilateral condition were significantly lower than the UL+UR condition for both men ($p < 0.001$) and women ($p = 0.009$). For FA, only men ($p = 0.0015$), but not women ($p = 0.11$) demonstrated greater UL+UR force value than that in the bilateral condition. In addition, the EMG amplitude for the left ($p = 0.04$) and right ($p = 0.034$) biceps brachii in the bilateral condition were significantly lower than those in the unilateral conditions. However, there were no difference in FDI EMG amplitude between two conditions for both sexes.

CONCLUSIONS: The BLD in EF can at least be partly explained by the decreased muscle activation during simultaneous maximal contraction of both limbs. Different from the EF, the BLD in FA is sex dependent, with women demonstrating more varied results than men. These differences may be due to the different motor control strategies being utilized in two muscles.

PIII.30 Cortical contribution to lower leg muscle function during quiet standing

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Several studies have addressed cortical contribution to balance during perturbation and conscious movement. However, no study has yet investigated the level of cortical contribution to postural control during quiet standing. Control of posture during standing is achieved largely through spinal stretch reflexes. This may then be fine tuned by cortical modification of muscle actions. It has been suggested that the cortex is involved in maintaining balance since balance ability can be modified by cognitive tasks. In this study experiments involve using transcranial magnetic stimulation (TMS) to assess the cortical contribution to lower leg muscle activation during quiet standing without perturbation and comparing this with a conscious isometric contraction of a lower leg muscle. A subthreshold paired TMS pulses were used to stimulate the leg area of the motor cortex while the participant is standing in a normal comfortable posture. Voluntary activation requires the participants to isometrically activate the tibialis anterior muscle at 10% maximal voluntary force. Electromyography was used to measure electrical activity of the muscle during the contraction with TMS and data analysed using the CUSUM method (1). In this preliminary study, the contribution of the motor cortex to maintaining posture during quiet standing with visual feedback was discernable with this technique showing inhibition whereas no inhibition was evident when not consciously maintaining the contraction. 1.Brinkworth RS & Türker KS. Journal of Neuroscience Methods, 2003.

PIII.31 Immediate changes in chest and pelvic kinematics after different types of trunk muscle exercises

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Introduction: Excessive and sustained activity of the superficial trunk muscles across the chest and pelvis may limit mobility of the chest and pelvis. To test this hypothesis, we examined the immediate effects of two trunk muscle exercises on mobility of the chest and pelvis.

Methods: Fourteen healthy men agreed to participate in this study. All participants performed trunk side flexion while lying down, and an abdominal draw-in exercise in the supine position using a cross over design. Three cameras were used to measure the kinematic data before and after each intervention during the following tasks: maximum inspiration/expiration and maximum pelvic anterior/posterior tilt while standing. A surface electromyogram was used to monitor muscle activity of the trunk and neck during each intervention. Image J was used to calculate the upper and lower chest areas, elevation distance, anteroposterior and lateral diameter, anteroposterior tilt angle, and lower extremity and neck angle in the sagittal plane using reflective markers affixed on the body. Two-way repeated measure analysis of variance was used to test between the intervention and period ($p<0.05$).

RESULTS: Muscle activity of the external oblique, internal oblique/transversus abdominis (IO/TrA), thoracic elector spinae, and scalenus during trunk side flexion and IO/TrA during draw-in were significantly greater than other muscle activities. There were significant interactions in the lateral diameter of the upper and lower chests during maximum inspiration, elevation distance of the upper and lower chests, and the anteroposterior tilt angle of the upper chest during maximum pelvic anterior tilt. The lateral diameter and elevation distance of the upper and lower chests after trunk side flexion was significantly less than those before intervention. The elevation distance and anteroposterior tilt angle of the upper chest after draw-in were significantly greater than those before the intervention.

Discussion: Our results showed that trunk side flexion decreased the mobility of the upper and lower chest in the sagittal and frontal planes during pelvic anterior tilt and maximum inspiration. Considering the results of muscle activity during trunk side flexion, the increased activity of the superficial abdominal muscles might be the limiting factor of chest mobility during maximum pelvic anterior tilt and inspiration. Meanwhile, the mobility of the upper chest in elevation distance and anteroposterior angle increased after draw-in. A previous study has reported an antagonistic interaction between the expiratory intercostal muscles and the abdominal muscles during expiration (De Troyer A, et al. 2005). The facilitated abdominal deep muscles in draw-in relaxed the expiratory intercostal muscles and increased mobility of the upper chest.

CONCLUSION: We conclude that exercise-facilitated superficial trunk muscles may decrease mobility of the chest.

PIII.32 Motor unit recruitment is altered, albeit slightly, when acute pain is induced in the an unrelated or antagonist muscle

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BACKGROUND AND AIM: Acute pain is associated with changes in the control of muscles near the painful region. Less is known about changes in movement control when pain is experienced at a distance from the contracting muscle. We aimed to determine whether acute experimental pain, induced by injection of hypertonic saline injection (5% NaCl), in an unrelated (tibialis anterior: TA - StudyTA) or antagonist (bicep femoris: BF - StudyBF) muscle, is associated with altered quadriceps control during force-matched isometric knee extensions (Control1, Control2, Pain).

METHODS: Vastus medialis (VM), vastus lateralis (VL), rectus femoris and BF muscle activity was recorded using surface electromyography (sEMG); VM and VL single motor unit (SMU) activity was recorded using intramuscular EMG (iEMG).

RESULTS: Force was maintained at 4.7±5.7 %MVC during StudyTA, and 3.3±2.8 %MVC during StudyBF. There was no difference in force between conditions within a study (all P>0.4). Participants reported a pain intensity of 4.3±1.6/10 and a pain area of 25.3±22.3 cm2 during PainTA, and pain intensity of 4.1±1.4/10 and pain area of 24.1±21.7 cm2 during PainBF. There was no change in sEMG between conditions in either study for any muscle (both P>0.6). SMU discharge rate was ~0.5 Hz lower during Pain than Control conditions, ControlTA: 8.7±1.4, PainTA 8.2±1.3; ControlBF: 8.5±1.5, PainBF 7.9±1.5; both P<0.001. A small redistribution of SMU activity was observed, which included some newly recruited and some de-recruited SMUs during Pain, in both studies. The decrease in SMU discharge rate during PainTA and PainBF (Cohen’s d: 0.26 and 0.31, respectively) was considerably smaller than previous experiments (Cohen’s d range: 0.52-0.84) when pain was experienced in or near the muscle producing force.

CONCLUSIONS: Previous works have shown that pain in an antagonist muscle is associated with a change in activity of the prime mover during dynamic, but not during static contractions (e.g. Graven-Nielsen et al, 1997). Consistent with this, we did not observe a change in prime mover muscle activity between conditions when using sEMG. Rather, the changes in muscle behaviour were only observed at the level of the SMU. Acute pain in an antagonist or in an unrelated muscle can influence SMU discharge in a contracting muscle. It is possible that changes in VL and VM SMU recruitment alter stretch and therefore stress within the BF during PainBF, however it is unlikely that the adaptations observed during PainTA could have unloaded the painful region. It is also possible that the changes observed in both studies relate to a decrease in net excitation to very low threshold SMUs, and the subsequent recruitment of slightly higher threshold SMUs that are then required to maintain the motor task. This is supported by animal (Knifke et al, 1979, 1981) and human (Hodges et al, submitted) studies that show smaller/lower threshold motor units receive greater inhibitory input from nociceptors.

PIII.33 Muscle activation patterns of the gluteus maximus and hamstrings during a prone hip extension assessment

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BACKGROUND AND AIM: There is a lack of consistent findings in healthy individuals to inform the activation patterns of the gluteus maximus (GMax) and the hamstrings during a hip extension movement, making it difficult for a clinician to identify dysfunction and establish appropriate rehabilitation. Therefore there is a need to explore the onset of muscle activation for the biceps femoris (BF), semitendinosus (ST) and the GMax during a prone hip extension (PHE) task and investigate sex differences in the onset times for these muscles. DESIGN: Cross sectional observational study design

METHODS: 12 male and 11 female healthy and recreationally active participants were recruited. Each participant performed three PHE trials using their dominant leg followed by three PHE movements for data collection. Surface electromyography (EMG) was used to record muscle activity for the GMax, BF and ST. A pressure pedal placed above the superior boarder of the patella was used to identify the onset of movement. Mean onset times relative to the onset of movement were calculated. Muscle onset was assumed when the signal deviated two standard deviations above a mean pre-movement value of activity. Descriptive statistics and a two-way analysis of variance was used to analyse the data.

RESULTS: Onset of muscle activity for the GMax, ST and BF all occurred prior to the onset of movement with the GMax activating last in 91.3% of participants. GMax activates significantly later than the BF ($P = 0.004$) and ST ($P = 0.009$). There was no significant difference in muscle onset times between sexes for the different muscles ($P = 0.757$).

CONCLUSIONS: Findings demonstrated a consistent muscle firing pattern with GMax often activating last and is significantly delayed in relation to the BF and ST. Additionally it should be noted that the contraction of all three muscles should occur prior to the onset of movement in a healthy population. Although further research is needed to fully understand the clinical relevance of this information with regard to assessment and rehabilitation. Further research is needed to confirm that there are no sex differences

PIII.34 Effect of relationship between kinematics and neuromuscular parameters on motor control during high-heeled gait

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BACHGROUND AND AIMS: Surveys on shoe use show that between 39% and 69% of young women wear high-heeled shoes on a daily basis to make them look longer or slimmer and more fashionable [1]. Although gait with high-heeled shoes may alter motor-unit recruitment and imbalance, studies have shown that the human motor control system has the ability to accommodate these changes [2]. To overcome the perturbations of the musculoskeletal system, the body needs to compensate the pressure by exerting more pressure on the muscles to achieve its balance. Therefore, the current paper aimed to analysis lower extremity muscle activities in different kinematics phase, to find out relationship between muscle activities and kinematics parameters to examine the effects of wearing high-heeled shoes during walking.

METHODS: Fifteen volunteers participated in the study (Age of 33 ± 32 years, height of 162 ± 42 cm, weight of 68 ± 92 kg). All data collection took part at the biomechanics laboratory at the University of Sharif (Moafaghian research center, Tehran, Iran). For kinematic analysis, 39 markers were placed on the subject's bodies. The barefoot and high-heeled gait were recorded at 200 Hz by 6 high speed camera (Vicon Industries Ltd., Hampshire, UK). The muscle activity of six muscles of both legs were recorded: the Vastus Medialis (VM), the Tibialis Anterior (TA), the Biceps Femoris (BF), the Semitendinosus (ST), the Gastrocnemius Medial (GM) and the Vastus Lateralis (VL). The EMG data acquisition was done with a sampling frequency of 1000 Hz. Raw EMG signals were digitally filtered (10-400 Hz) and the full wave was rectified and smoothed by with a low pass filter of 8 Hz (Butterworth, 4th order).

RESULTS: The normalized EMG and kinematics data collected during gait in women wearing high-heel shoes and barefoot condition are presented in Fig. 1. Heel height significantly affected the EMG activity of the VM and ST muscles. Although, Heel height more or less affected the EMG activity of all muscles. In both conditions, the major differences in peak joint angle between groups occur at heel strike phase. While wearing high-heeled shoes, the changes at the proximal joints mainly take place in the frontal and transverse planes and larger hip internal rotation and less external rotation, less hip adduction, and larger knee adduction. As compared with the barefoot group, the high-heeled shoes group demonstrates less hip and knee angle before 20% of gait cycle. Most of peak angles occur at transiting from stance to swing phase. Figure 1: Neuromuscular and kinematics variables of lower limb during gait in barefoot and high-heeled groups.

CONCLUSION: This study showed that the kinematics parameters and EMG activity differed significantly between barefoot and high-heeled groups. It seems that wearing high-heeled shoes affects the distal muscles of the lower limbs compared to the proximal muscles. The sustained and repeated wearing of high-heeled shoes with excessive heights can induce inappropriate neuromuscular behaviors due to muscular imbalance. This study has produced clinically useful parameters on the effects of heel height on neuromuscular and kinematics changes; this study has confirmed that it is imprudent for women to repeatedly wear high-heeled shoes, and the obtained data can provide information to assist the clinician in identifying and analyzing the gait, and in determining appropriate interventions.

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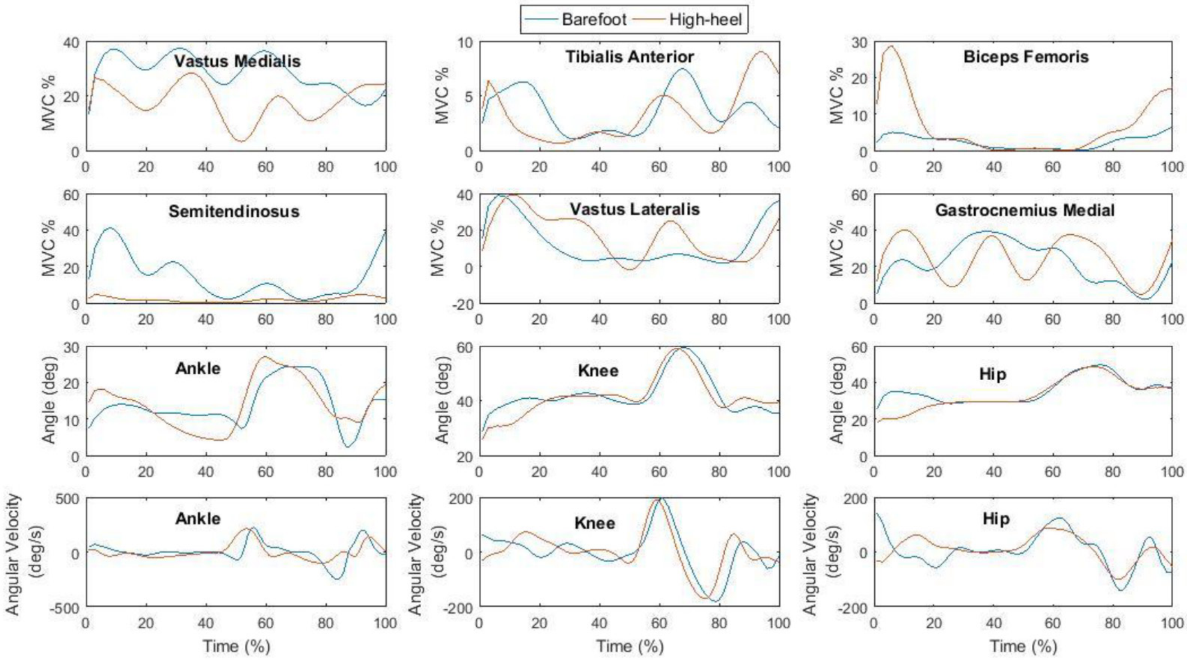
Barefoot
High-heel
Vastus Medialis
Tibialis Anterior
Biceps Femoris
Semitendinosus
Vastus Lateralis
Gastrocnemius Medial
Ankle
Knee
Hip
Ankle
Knee
Hip
MVC %
Angle (deg)
Angular Velocity (deg/s)
Time (%)

MOTOR DISORDERS & NEURPHYSIOLOGY

PIII.35 Functional interhemispheric connectivity of motor cortices in ALS

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BACKGROUND AND AIM: Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease of primarily upper and/ or lower motor neurons resulting in progressive loss of bulbar and limb function [1]. A number of network studies have shown that this neurodegeneration is accompanied by abnormal functional connectivity in motor networks. Previous fMRI studies have identified increased connectivity in the left motor cortex (MC) in ALS patients [2]. This finding was supported by our EEG resting-state study, wherein we found increased interhemispheric coherence on the scalp over motor areas in the theta frequency band [3]. Additionally, diffusion tensor imaging studies have shown structural degeneration in the motor-associated body of the corpus callosum (CC) in ALS patients [4]. Further investigation is now warranted to elucidate the underlying disease pathophysiology by identifying the nature and patterns of connectivity in more specific regions of the affected motor networks. This study aimed to further characterise the altered interhemispheric connectivity between motor areas in ALS using both amplitude- and phase-based measures of functional association in the source space.

METHODS: Resting-state EEG was recorded from 128 channels for 6 minutes from 33 ALS patients and 13 healthy controls. Linearly Constrained Minimum-Variance beamforming was used to estimate the electrical source strength over time in the proximity of 6 predefined points in the MC (3 left; 3 right). The interhemispheric connectivity was assessed using two measures: amplitude envelope correlation (AEC) and the phase-based measure imaginary coherence (IC). These measures were estimated in 8 frequency bands.

RESULTS: Preliminary results show a statistically significant decrease (Mann-Whitney U-test, $p = 0.003$; adaptive false discovery rate, $q = 0.05$) in interhemispheric AEC between motor cortices in ALS patients in high beta-band. Similarly, we found a marginally significant decrease ($p = 0.034$, $q = 0.05$) in IC in low alpha-band.

CONCLUSIONS: We have assessed 2 connectivity measures that may reflect two different neuronal circuit mechanisms. Amplitude envelope correlation measures co-variation of the power between two areas (known to be similar to slow fMRI fluctuations at very low frequencies). These fluctuations are thought to be driven by common neuromodulatory systems in the brainstem; hence, the decrease of AEC in high beta-band in ALS supports previous findings of neuronal degeneration and dysfunction in the brainstem [5]. In addition to this, the IC results suggest impaired low alpha-band phase synchrony between motor cortices in ALS patients that could be attributed to degeneration of the CC.

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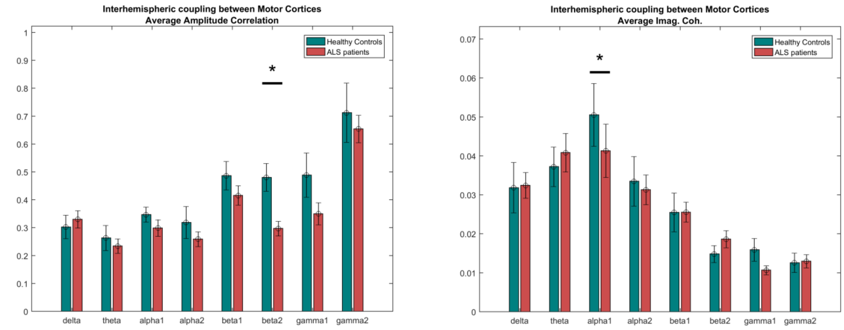

Figure 1. Interhemispheric coupling between motor cortices in ALS patients and healthy controls. The coupling is measured using amplitude envelope correlation, AEC, (left) and imaginary coherence, IC, (right). The significant difference is reached in the high beta-band for AEC, whereas for IC it is reached in the low alpha-band.

PIII.36 Assessing Cortico-Muscular Communication in Motor Neuron Disease

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BACKGROUND: Motor Neuron Disease (MND) is often seen as a neurodegeneration process that is primarily characterized by the progressive loss of upper and lower motor neurons (U/LMNs), leading to severe motor impairment. The emerging evidence, indicates impairments beyond the traditional UMN pathology, including degeneration in other brain pathways and possible disruptions in broader motor networks in MND. Assessment of neurodegeneration in the context of impaired network communication can provide a better understanding of the underlying disease mechanism. This network dysfunction can distort the central-peripheral communication in the motor system; however, it still remains one of the lesser studied areas in MND with potential to provide new insights to patient stratification in the future. Joint recording of multi-channel electroencephalogram (EEG) and electromyogram (EMG) for time-series analysis can potentially be used to quantify the level of effective communication between all cortical brain regions while quantifying the oscillatory motor drives to muscles during motor tasks. We hypothesize that cortico-muscular coherence (CMC) between EEG-EMG can inform on the specific alterations in the brain's motor networks within and beyond the primary motor cortex in MND. AIM: To study CMC as a potential tool for assessing network disruption in selected motor subsystems in MND patient subgroups during functional isometric motor tasks.

METHODS: High-density 128-channel EEG and 8 bipolar surface electromyographic recordings from both extrinsic and intrinsic hand muscles were obtained from 15 patients with dominant upper (primary lateral sclerosis), lower (Poliomyelitis) and mixed upper/lower (amyotrophic lateral sclerosis) motor neuron degeneration as well as from 3 healthy controls, during their performance of a series of isometric precision grip tasks.

RESULTS: Preliminary analysis of data from one participant in each patient group and controls indicated that frequency, location and intensity-specific features of CMC distinguish the healthy controls from the patient groups. These differences included an alpha-band increase over frontal regions (PLS patient) and delta-band increases over central and right frontal regions (Polio patient).

CONCLUSIONS: While further analysis is required to fully characterize the pathological CMC in MND, the distinct signatures exhibited by the MND patients suggest that this methodology may provide a means of unmasking altered neural communication in the broader motor brain networks. The CMC in healthy individuals is observed over contralateral motor regions. In MND, the dominant degeneration occurs in corticospinal tract, which could affect the CMC over primary motor areas. However, the detection of abnormal patterns of CMC in patient groups over scalp regions other than the primary motor (M1) area may reflect activity in other cortical regions compensating for loss of normal M1 corticospinal projections.

PIII.37 Trunk instability with shank muscle co-contraction is masking the potential of walking ability in patients with post stroke hemiplegia

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BACKGROUND AND AIM: Walking ability in patients with post stroke hemiplegia (PSH) was strongly related to severity of lower limb motor paralysis. In clinical scenes, some patients showed poor walking ability despite mild motor paralysis. On the other hand, some patients showed a good walking ability despite severe motor paralysis. In this study, we aimed to investigate the relationships between walking speed and degree of lower limb motor paralysis and analyze the characteristics of kinesiology and electromyography related it.

Methods: Thirty-five patients with PSH were participated in this study (age: 67.3 ± 17.2 years old, after onset: 136.7 ± 119.7 days). The patients were asked to walk a 10m of distance at a conventional speed (use of walk aid was permitted) and walking speed of 10m of distance, electromyography (EMG) and trunk acceleration were simultaneously recorded. Specifically, EMG were recorded in medial gastrocnemius and tibialis anterior on affected sides and co-contraction index were calculated to evaluate the stiffness of shank muscle in walking cycle. Also acceleration of X,Y,Z plane was recorded in L3 spinous process to evaluate the trunk control ability in walking cycle. Subsequently, the patients were evaluated the synergy score of fugl-meyer assessment (FMS) for confirming the degree of lower limb motor paralysis.

RESULTS: Walking speed and FMS showed a significantly linear correlation ($r=0.51$, $p<0.01$). However, some patients showed poor/good walking ability despite mild/severe motor paralysis. To analyze the characteristics of these cases, we conducted hierarchical cluster analysis using walking speed and FMS. As a result of cluster analysis, following four clusters were extracted; 1)poor to modulate paralysis and lower slow walking speed, 2)severe motor paralysis and slow to modulate walking speed, 3)modulate motor paralysis and modulate to advance walking speed, 4) mild motor paralysis and advanced walking speed. Interestingly, Cluster 1 in which the slow walking speed despite the good paralysis showed low trunk control ability with higher co-contraction of shank muscles.

CONCLUSIONS: Those results suggested that co-contraction of the lower leg muscles to compensate for the trunk instability may be a masking the potential of walking ability.

PIII.38 Myoelectric manifestations of fatigue in people with multiple sclerosis

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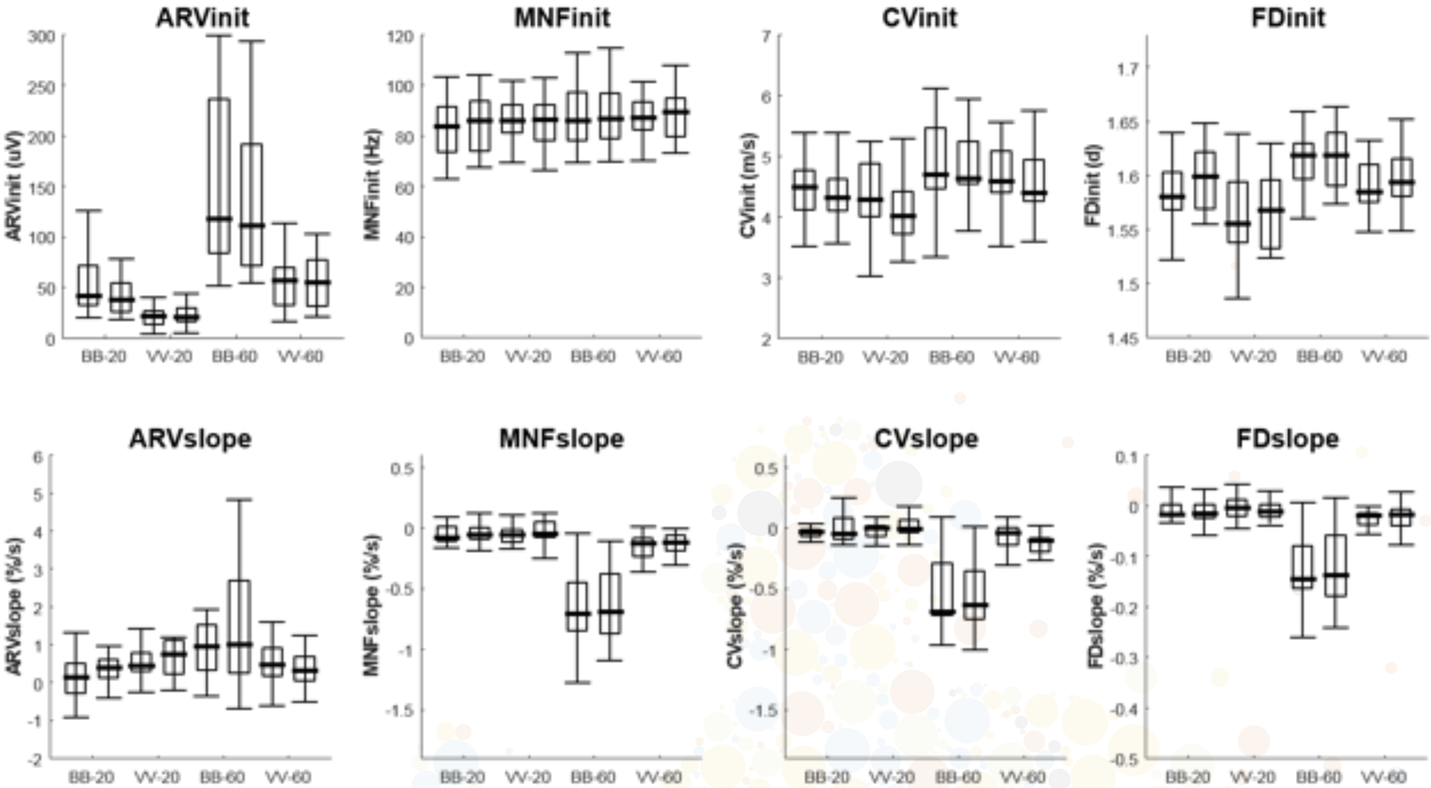
Background and aim: People with multiple sclerosis (pwMS) often show abnormal muscle fatigability, caused by reduced central activation and neural drive to the muscles (central fatigue), resulting in altered motor units (MUs) recruitment and decreased maximal voluntary MU firing rate. However, during rehabilitation, there is no common conclusion regarding the effects of MS on fatigue at a neuromuscular level. Recent data suggest that insufficient drive to the muscle result in a lower degree of peripheral fatigue. Thus, the main objective of this pilot study was to investigate, if linear and non-linear surface electromyographic (EMG) parameters are suitable to describe central and peripheral components of muscle fatigue in severely fatigued pwMS. Moreover, we assessed changes in fatigue and fatigability in pwMS after a 3-week rehabilitation program.

METHODS: 21 pwMS participated in a pre- and post-rehabilitation observational study designed to determine changes in perceived fatigue and motor fatigability. pwMS were asked to complete the Fatigue Scale of Motor and Cognitive functions (FSMC) at entry (T0) and 4 weeks after discharge (T2). Muscle fatigue was evaluated using bi-dimensional arrays at T0 and after a 3-week rehabilitation program (T1) considering changes in the following parameters: average rectified value (ARV), mean frequency (MNF), conduction velocity (CV) and fractal dimension (FD) of sEMG. Myoelectric signals were detected in monopolar configuration from vastus lateralis and medialis (VV) and biceps brachii (BB) muscles during isometric knee extensions and elbow flexions, at 20% and 60% MVC.

RESULTS: Although the total scores of the FSMC at T0 compared to T2 resulted in a slight decrease (not significant), self-reported fatigue remained severe after rehabilitation. Moreover, no significant changes were observed in MVC force and the considered sEMG parameters between T0 and T1. Nevertheless, rate of changes of MNF and CV were significantly less negative -and of ARV less positive- during the high-level fatiguing contraction of the VV muscles, compared to the BB muscle pre- and post-rehabilitation (Figure) ($p<0.05$).

CONCLUSIONs: Since MS usually affects predominantly the lower limb, it was expected that the VV muscles would have been more fatigued compared to the BB. Unexpectedly, this pilot study showed reduced peripheral motor fatigability in the VV muscle of pwMS. Consequently, our results suggest that, due to the fact that MS is a neurological disorder with prominent central involvement, the lack of drive protected the muscle getting exhausted. Thus, changes in the EMG output in the VV muscles were much more limited, showing less motor fatigability, with respect to the BB.


ARVinit
ARVinit (uV)
MNFinit
MNFinit (Hz)
CVinit
CVinit (m/s)
FDinit
FDinit (d)
ARVslope
ARVslope (%/s)
MNFslope
MNFslope (%/s)
CVslope
CVslope (%/s)
FDslope
FDslope (%/s)
BB-20
VV-20
BB-60
VV-60

PIII.39 The effect of Exercise on Plantar Pressure Distrubition in Children with Hemiplegic Cerebral Palsy

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BACKGROUND AND AIM: Impaired balance and postural asymmetry have observed to some extent in children with hemiplegic cerebral palsy (CP), depending of the lesion severity. The information about plantar foot pressure distributions between the affected and unaffected limb may be helpful to evaluate the pattern of weight bearing, design of orthosis and exercise program. The aim of this study was to investigate the effect of exercise program on plantar pressure distribution and balance between the unaffected and effected feet in children with hemiplegic CP.

METHODS: 9 Children with hemiplegic CP (mean age: 7.82 ± 2.89; GMFCS: I and II) were recruited in this study. Static plantar pressure distribution measurements were recorded when the subjects stand quietly on a force plate, which measured vertical ground reaction forces. TekScan system was used with scanning speed of 100 Hz. The Center of force (COF/COP) data was automatically recorded by the system's software during double leg static balance task for 30 sec. Matscan pressure mapping system software was used for the interpretation of the data. Firstly, COP area outcome variables were evaluated: COP Area, COP distance, antero-posterior (COP AP) and COP medio-lateral (COP ML) sway. Secondly, the best COP Area value from the trials was selected to analyze plantar pressure distribution. Thirdly, mean of the peak contact pressure (PCP) was calculated for forefoot, mid-foot, rear food and total plantar foot pressure. Training programs were performed for approximately twelve week. Each exercise session consist of strengthening, balance, and flexibility and coordination talents and lasted 75 min.

RESULTS: Three months functional exercise program may not provide enough improvement for COP balance parameters in children with CP (p>0.05). The percentage and mean values of PCP among three region of foot were similar between pretest (unaffected side; forefoot: 216,8 gr/cm2 (30%), midfoot: 159 gr/cm2 (17.5%) and 355.94 gr/cm2 (52%); hemiplegic side; forefoot: 239 gr/cm2 (30.5%); midfoot: 202 gr/cm2 (25%) and 359 gr/cm2 (44.5%) and post-test (unaffected side; forefoot: 224.39 gr/cm2 (32.2%); midfoot: 153.4gr/cm2 (16.2%) and 364.4gr/cm2 (51.5%); hemiplegic side; forefoot: 216.1 gr/cm2 (29.7%); midfoot: 188 gr/cm2 (25%) and 349 gr/cm2 (45.3%)). Similarly, when unaffected and hemiplegic side foot compared, both pretest and posttest values for mean of PCP were higher in midfoot of hemiplegic side than unaffected side, although there was no statistical difference (p>0.05). Galli et al. (2015) showed that in normal healthy population, plantar foot distribution was almost in the same rate of distribution of contact pressure between rear and fore foot. Our data for hemiplegic children were different for rear and fore foot PCP during static stance. This may be the result of voluntary weight transfer to the rear foot during recording.

CONCLUSIONS: In this study, the main finding is that the contact pressure distribution was in similar rate for both legs after three months exercise program. Distribution of plantar pressure assessment may give important individual information on how the foot loaded by the child's body during training/rehabilitation program. Next studies should be focused on both standing and walking with children with CP.

PIII.40 Does the myoelectric fatigue manifest locally on pectoralis major muscle during inclined bench press exercise?

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AIM: The muscle fatigue is mechanically characterised by a decline in force production and occurs during vigorous or prolonged contractions [1]. It has been demonstrated that previously to the muscle mechanical failure, electrophysiological alterations arise termed as myoelectric manifestations of fatigue (MMF) [2]. With multichannel surface electromyography, it was demonstrated that the MMF could manifest locally within the muscle [3]. During the inclined bench press exercise, previous evidence suggested that the pectoralis major (PM) clavicular region would be more activated than PM sternocostal region [4]. If this occurs, it is reasonable that the fatigue might also manifest locally during that task until the failure. Thus, the purpose of the present study is to investigate whether the MMF would be more evident near to the PM clavicular region during 15 maximum repetitions of inclined bench press exercise.

METHODS: While laying comfortably on an inclined bench at 45deg, three healthy males were instructed to perform 1 set of 15 repetitions using a 50% of 1 maximal repetition load. The grip was defined as 200% of biacromial distance and the movement velocity was controlled with metronome (2s each movement phase). An array of 16 electrodes perpendicularly positioned to PM fibres was used to sample EMGs. The adhesive array was medially placed from the PM innervation zone (previously defined) and covering the entire cranio-caudal axis. The root mean square (RMS) of EMGs were computed for each of differential channel and separately for the 15 concentric phases. The RMS values were averaged across channels aiming to obtain representative values from the four PM regions: cranial (from channel 1 to 3); centro-cranial (from 4 to 7); centro-caudal (from 8 to 11); caudal (from 12 to 15). Finally, the fatigue plotting was obtained for each PM region [2]. The results were presented separatelly for each subject.

RESULTS: For 2 subjects, the cranial and centro-cranial regions respectively presented the highest RMS amplitude variations along the 15 concentric repetitions (i.e., a higher inclination of the regression line on the fatigue plotting). For one case, this behavior was not observed, with the centro-cranial and centro-caudal regions having a greater slope of the fatigue plotting regression line.

inclined bench press exercise. Specifically, from 2 out of 3 participants the MMF was consistently more evident closer to the cranial region. However, since a small number of individuals were investigated, we are currently increasing the sample to verify these results in a large number of participants.

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PIII.41 Effect of indirect vibration on sensorimotor transmission in the human upper limb

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BACKGROUND AND AIM: Acute Indirect vibration delivered through upper or lower limbs can enhance force, power, flexibility, balance, and proprioception and it continues to gain popularity as a modality for sport, exercise, and physical rehabilitation. However, the neuromuscular mechanisms underlying its potentiating effects have yet to be firmly established. Therefore, the objective of this study was to assess sensorimotor transmission in the human upper limb during indirect vibration to determine potential neuromuscular contributors.

METHODS: Twelve neurologically intact human participants completed a single experimental session. All measures were assessed under VIBRATION (Indirect vibration; 30 Hz; 0.4mm displacement) and CONTROL (No vibration) conditions. Indirect vibration was delivered to the upper limb muscles via custom-built device that participants held throughout the experiment. All conditions were assessed during a 10% peak muscle activity contraction of the right flexor carpi radialis (FCR). Corticospinal excitability was assessed by the amplitude of motor evoked potentials (MEPs) in the FCR evoked by transcranial magnetic stimulation delivered to the contralateral motor cortex. Reflex pathways were assessed using single 1ms electrical stimulation pulses delivered to median nerve (MED) proximal to the elbow to evoke both motor waves (M-waves) and Hoffmann reflexes (H-reflexes) in the FCR and normalized to the maximally evoked motor response (Mmax). In separate trials, a conditioning paradigm was employed in which a train of stimulation was delivered to the superficial radial nerve at the wrist 37ms prior to MED stimulation. M-wave amplitude was matched between experimental conditions and was not different between CONTROL and VIBRATION or during the conditioning paradigm ($p>0.05$).

RESULTS: There was no significant effect of VIBRATION on MEP amplitude ($p>0.05$). H-reflexes were significantly facilitated during the conditioning paradigm (16.8±8.0 vs 25.6±19.5 % Mmax; $p<0.05$). VIBRATION significantly reduced H-reflex amplitude similarly for conditioned and unconditioned reflexes (24.0±15.7 vs 18.4±11.2 % Mmax; $p<0.05$).

CONCLUSIONS: These results are consistent with the idea that acute indirect vibration in the upper limb induces pre-synaptic inhibition of 1a sensorimotor transmission however may not influence corticospinal excitability of the forearm flexors.

PIII.42 Interhemispheric Facilitation of Corticospinal Pathways Induced by Short Duration tACS

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BACKGROUND AND AIM: Interhemispheric facilitation (IHF) is an electrophysiological phenomenon that is prototypically elicited by paired-pulse transcranial magnetic stimulation (TMS). It is obtained when a sub-threshold magnetic conditioning stimulus (CS) is applied to one primary motor cortex (M1) shortly before (6 ms) a second supra-threshold (test) stimulus is delivered to the opposite M1, and produces an MEP with a larger amplitude than that produced by the test stimulus alone. In a previous investigation (Capozio et al., submitted), we demonstrated that pairing brief (500 ms) epochs of transcranial alternating current stimulation (tACS) applied to one M1 with supra-threshold TMS (120% rMT) applied to the homotopic region of the opposite M1, produced long-lasting increases in corticospinal excitability (ISI = 6 ms). Despite observing these chronic facilitatory effects, the peak-to-peak amplitudes of MEPs elicited during the induction protocol did not differ significantly from control (i.e. no IHF). It is increasingly recognised that TMS activates distinct populations of neurons (with varying degrees of functional connectivity) depending on the direction of the cortical eddy current (CEC). CECs that traverse the postero-anterior (PA) axis of M1 generate compound motor action potentials that express the contributions of several descending volleys (I1, I2, I3, etc.). Those that traverse the antero-posterior (AP) axis are believed to preferentially recruit later I3 waves. The MEPs thus generated may reflect, in particular, the state of polysynaptic inputs to M1. We reasoned that the interhemispheric effects of tACS on the output circuits of the opposite M1 are most likely mediated via pathways with respect to which MEPs elicited by AP (but not PA) currents are especially sensitive.

METHODS: Brief epochs of tACS were paired with supra-threshold AP TMS (120% rMT) to the opposite M1, using an inter-stimulus interval of 6 ms. The duration (6, 12, 30, 100, 500 ms) and frequency composition (140, 670, 100-640 Hz) of the tACS was systematically varied. The peak-to-peak amplitudes of MEPs elicited by tACS-TMS were contrasted with those of a control condition in which AP TMS was delivered alone.

RESULTS: In partial support of our hypotheses, we observed that the amplitudes of MEPs elicited by tACS-TMS (30 ms 140 Hz) were greater ($p=0.02$) than those elicited by TMS alone (i.e. IHF). In contrast, when the CS consisted of a 500 ms burst of 670 Hz tACS, MEPs were reduced ($p=0.03$) in amplitude relative to control (all other contrasts, $p>0.13$).

CONCLUSIONS: These findings suggest that when the test stimulus is AP TMS, brief conditioning bursts of tACS may have the capacity to produce both IHF-like effects and those that resemble interhemispheric inhibition (IHI). The degree to which the expression of these effects is amenable to reliable control through the systematic manipulation of tACS frequency and duration parameters remains to be further established.

PIII.43 The Common Drive Index Does Not Change in Patients in an Acute Phase After an ACL Reconstruction Surgery.

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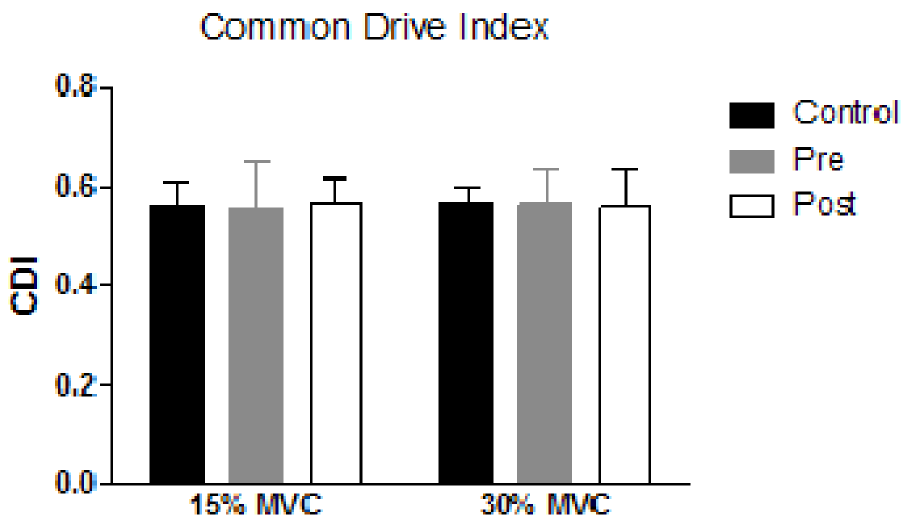
MEDS clinics

Background and Aim: The concept of common drive was described by De Luca as a strategy used by the nervous system to control a pool of motor units, rather than motor units in an individual way. (De Luca CJ, 1982;). The common drive has been investigated in; effects of fatigue on intermuscular common drive, De Luca CJ, & Mambrito 1987, different levels of the common drive of motor units during fatiguing isometric leg extensions, Contessa et al, eccentric exercise, influences of dynamic exercise on common drive, among others. However, there is no background in relation to common drive index of motor units in patients who underwent ACL surgery. The main objective of this work is to evaluate the changes in the common drive index in patients in a postoperative acute phase in ACL surgery Subjects: Individuals with ACL injury: 14 patients aged 18-50 years old of both genders diagnosed with isolated ACL tear or in addition to a meniscal tear and undergoing reconstructive surgery within 3 to 5 weeks of the ACL injury using the semitendinosus tendon graft was targeted. This project will be approved by the Ethics committee of health ministry

METHODS: The subjects performed a trapezoidal force motor task at two strength levels, 15 and 30% of the MVC respectively. The subjects were evaluated a day before the ACL surgery and one month after the reconstructive surgery, (acute phase) Four bipolar surface electromyography signals were detected from vastus lateralis (VL) during a trapezoid task with a specialized 5 P-pin surface array electrode. (Delsys, Inc, Boston MA). The skin was shaved and cleaned with alcohol before placing the sensor over the muscle. The collection of the EMG analog signal was made with a Bagnoli desktop system (Delsys Inc, Boston Massachusstes). The signals were sample at 20kHz, high pass filtered (cut off frequency of 20Hz), low pass filtered (cut off frequency of 1750 Hz) and they were stored to analyze them later. The signals were processed and decomposed into their motor unit action potential trains (MUAPs) with the Precision Decomposition (PD) III algorithm described by De Luca et al. The Common Drive Index was quantified by cross correlating the mean firing rate curves from the VL. All possible combinations of motor unit firing rates from the VL muscle were cross-correlated with each other. The peak cross-correlation coefficient was calculated from each cross-correlation function.

RESULTS: There were no significant differences in the Common Drive Index for 15% and 30% of MVC between pre and post ACL surgery patients and when compared with a control group.

CONCLUSIONs: The Common Drive Index is preserved in patients who underwent an ACL reconstruction surgery (acute phase).


Common Drive Index
CDI
0.8
0.6
0.4
0.2
0.0
15% MVC
30% MVC
Control
Pre
Post

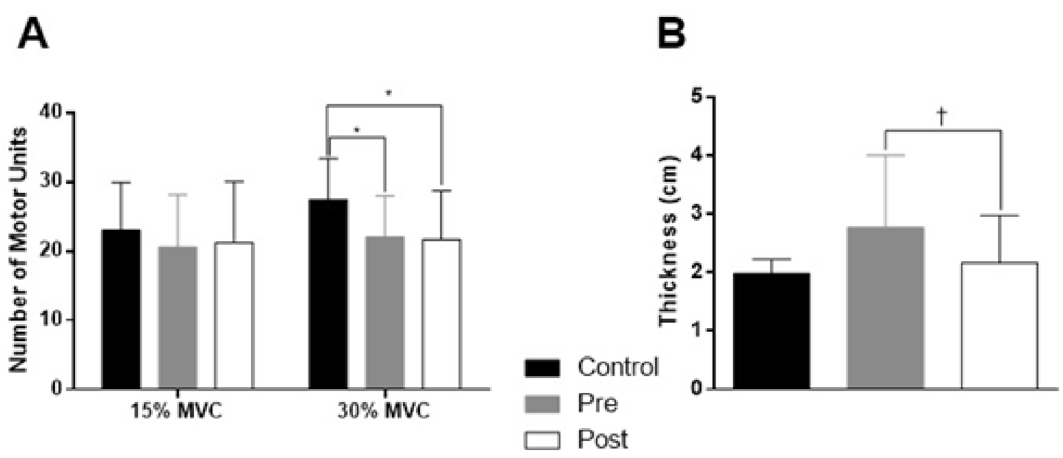
PIII.44 Muscle Thickness and Motor Unit Number of Vatus Lateralis Muscle in an Acute Phase After an ACL Reconstruction.

Macarena Soldan, Rony Silvestre, Iver Cristi, Vicente Cristi
MEDS clinics

Background and Aim: The anterior cruciate ligament (ACL) rupture is one of the most disabling injuries in young-adult. In addition, those who have suffered an ACL injury have a 40 to 50 times risk of suffering a new rupture of the cruciate ligament compared to healthy subjects (Hoch, 2017). The main criteria to discharge these patients are muscle strength and functional tests; however, there is no background about measuring structural and electrophysiological variables using ultrasonography and motor unit decomposition techniques. The main objective of this work is to evaluate changes in muscle thickness and number of motor units recruited in patients in a postoperative acute phase of ACL surgery.

METHODS: 14 patients aged 18-50 years old of both genders diagnosed with isolated ACL tear or in addition to a meniscal tear and undergoing reconstructive surgery using the semitendinosus tendon graft were selected. This project was approved by the Ethics committee of Health Ministry. Subjects performed a trapezoidal force motor task at two strength levels, 15 and 30% of the MVC. They were evaluated a day before the ACL surgery and one month after the reconstructive surgery. Four bipolar surface electromyography signals were detected from vastus lateralis (VL), during a trapezoid task with a specilizaded 5 P-pin surface array electrode (Delsys, Inc, Boston MA). The collection of the EMG analog signal was made with a Bagnoli system (Delsys Inc, Boston Massachusstes). The signals were sample at 20kHz, high pass filtered (cut off frequency of 20Hz), low pass filtered (cut off frequency of 1750 Hz). The signals were processed and decomposed into their motor unit action potential trains (MUAPs) with the Precision Decomposition (PD) III algorithm described by De Luca et al. A B-mode ultrasonography device was used to measure muscle thickness in millimeters of the VL. A linear ultrasound probe of 7.5 MHz, Inosight Phyllips, at 48 Hz was used for this purpose. The probe was positioned over the skin site that was evaluated with the array sensor for decomposition. Subsequently, images of the axial plane of the VL were obtained. The average thickness values of the VL were analyzed for statistical analysis.

RESULTS and Conclusions The number of motor units recruited before and after ACL reconstruction surgery at 30 % of MVC showed significant differences (pre = 22.0 (5.9) and post = 21.6 (7.0)) to 30 % MVC, however, for the 15% of MVC (pre =20.5 (7.5) and post= 21.2 (8.8)) there were no significant differences. Moreover there were significant differences between the number of motor units recruited before and after surgery when compared with a control group. On the other hand, the muscle thickness of VL muscle, did show significant differences before and after the ACL reconstruction surgery in an acute phase (pre = 2.77 (1.23) and post = 2.16 (0.8)) (* = p <0.05), but didn´t show significant differences with the control healthy group.



PIII.45 Effect of Spinocerebellar Ataxia On Muscular Activity in Jaw Postural Conditions

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BACKGROUND AND AIM: Spinocerebellar ataxia is a neurological disorder manifested in motor functions, with progressive dysfunction in cerebellum. This study aimed to analyze the electromyographic activity in the temporalis and masseter muscles of individuals with ataxia.

METHODS: 28 individuals were distributed in two groups: with spinocerebellar ataxia (n=14; mean ± SD 44 ± 3 years) and without the disease (n=14; mean ± SD 43 ± 3 years). The temporalis and masseter muscles were evaluated bilaterally with surface electromyography in clinical conditions: jaw rest, maximal voluntary contraction (normalization factor), protrusion, right and left laterality. This study was approved in the Ethics Committee from Ribeirão Preto Dental School, University of São Paulo, Ribeirão Preto, Brazil. The results of normalized electromyography were analyzed statistically (t-test; $P < 0.05$).

RESULTS: The results showed higher electromyographic activity of the temporalis and masseter muscles in all postural conditions of the jaw for the group with spinocerebellar ataxia, with significant difference for the right temporal ($P=0.01$) and left temporal ($P = 0.05$) muscles on protrusion; right temporal muscle on right laterality ($P =0.02$) and left laterality ($P =0.01$).

CONCLUSION: This study suggests that the stomatognathic system of individuals with ataxia presents increased the electromyographic activity of masticatory muscles. ACKNOWLEDGEMENT: FAPESP and CNPq

PIII.46 Distinguishing clinical phenotypes in basal ganglia disease using wrist-worn accelerometers during the Clinch Token Transfer Test

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[1]Cardiff University, [2]Insight Centre for Data Analytics

Introduction: Parkinson Disease (PD) and Huntington Disease (HD) are both degenerative, neurological disorders resulting in a disabling movement disorder. Whilst the diseases have unique pathological features they share similar features. Such features include are hypokinesia, bradykinesia, rigidity and resting tremor in PD and bradykinesia, chorea and dystonia in HD. The Clinch Token Transfer Test (C3t) is a novel clinical tool suitable for standardising the assessment of upper limb biomechanical function of participants. This study examines the potential for using tri-axis accelerometers worn whilst taking the C3t to distinguish between the clinical phenotypes seen in HD and PD in comparison to controls.

Methods: Two GENEActiv tri-axis accelerometers (sample frequency = 100hz) were worn on the wrists of both hands of 10 manifest-HD, 8 PD and 9 control participants whilst they took the C3t. Time and frequency domain features, listed in Table 1, were extracted for each task of the C3t using acceleration along each axis as well as the absolute acceleration (defined as √ (x^2+y^2+z^2)) for both sensors. Feature selection was performed using the Scikit false positive rate algorithm with a linear-kernel support vector machine (SVM) inside a stratified k-fold cross-validation (CV) loop (k=8). Selected features were then evaluated inside a second CV loop using another linear-kernel SVM. Models were built and evaluated using 3 and 2 features. Three SVM models were developed. SVM1 to distinguish between HD, PD and controls, SVM-HD to distinguish HD from controls and PD, and SVM-PD to distinguish PD from controls.

RESULTS: SVM1 had, in order and from the perspective of the HD, PD and control groups, a balanced accuracy of 89.1%, 82.25% and 69.15%, sensitivity 90, 75, 55 and specificity 83.3, 89.5 and 83.3. SVM1 was generated using the SEF-95 and SEF-25 of the non-dominant hand z-axis during the baseline-value task (BVT) and complex-value task (CVT) of the C3t respectively. SVM-HD had a balanced accuracy of 92.05%, sensitivity of 90 and specificity of 94.1 and was generated using the z-axis sample entropy of the dominant and non-dominant hands during the BVT. SVM-PD had a balanced accuracy of 93.75%, sensitivity of 87.5 and specificity of 100 and was generated using the SEF-75 of the non-dominant hand z-axis during the Complex Transfer Task and SEF-25 of the non-dominant hand x-axis during the CVT.

Discussion: SVM1 performed rather poorly, especially at classifying controls however SVM-HD and SVM-PD performed much better and could be used to fulfil the same proposed role as SVM1 if used in conjunction with each other (i.e. first separate HD from controls and PD and then separate PD from controls). Whilst this study is useful for establishing proof of principal that wrist-worn accelerometers combined with the C3t may be capable of distinguishing between controls, HD and PD with a high degree of accuracy more work is needed to enhance the quality and validity of the model. Future work will specifically focus on applying more advanced feature engineering methods, especially ones which are relatable to disease-related clinical phenotype, as well as increasing the size of the dataset.

Feature	Description
a_{mean}, $a_{average}$, a_{std}	Mean, average and standard deviation of acceleration
j_{mean}, $j_{average}$, j_{std}	Mean, average and standard deviation of jerk, first derivative of acceleration
SampEn	Sample entropy of acceleration
SEF-95, SEF-75, SEF-50, SEF-25	95^{th}, 75^{th}, 50^{th} and 25^{th} spectral edge frequencies
F_d	Dominant Frequency
F_p	Peak power frequency
SampEn-diff	Difference in sample entropy between first and last task of the C3t
$jdiff_{mean}$, $jdiff_{average}$, $jdiff_{std}$	Difference in mean, average and standard deviation jerk between first and last task of the C3t

Table 1 – List of generated features and description

MOTOR PERFORMANCE & SPORTS SCIENCE

PIII.47 Reliability of knee-extensor neuromuscular function assessment and fatigue in a healthy female population

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BACKGROUND AND AIM: Mechanisms of altered neuromuscular function (NMF) can be determined at various levels of the motor pathway using single and paired pulse transcranial magnetic stimulation (TMS), and electrical stimulation of the motor nerve (MNS). Although these techniques have been used to assess NMF of the knee-extensors in female populations (e.g. [1]), reliability data for such measures in the population is unknown.

METHODS: Fourteen young females taking the combined monophasic oral contraceptive pill (OCP) completed two identical experimental sessions within 2-5 days during the final 2 weeks of their pill cycle. Test-retest reliability of NMF of the knee-extensors was assessed pre-exercise, and following an intermittent, isometric fatiguing task to failure. Electromyography (EMG) was recorded with surface electrodes from the rectus femoris. Maximum voluntary contraction (MVC) force, contractile function (Qtw.pot), voluntary activation (VA; using TMS and MNS), the maximal compound muscle action potential (Mmax), corticospinal excitability (MEP/Mmax), cortical silent period (CSP) and short interval intracortical inhibition (SICI) were assessed before and after exercise. Performance fatigability was assessed as the time to task failure (TTF) of the isometric fatiguing task. Typical error (TE), intraclass correlation coefficient (ICC), and 95% limits of agreement were calculated for most variables; ICCs were not calculated for VA variables due to the ceiling effect. TE was expressed as a percentage of the mean, but as a raw percentage for VA, MEP/Mmax, and SICI.

RESULTS: Pre-exercise MVC (TE: 4.3%, ICC: 0.96), Qtw.pot (TE: 5.1%, ICC: 0.90), VA assessed with MNS (TE: 1.6%) and TMS (TE: 3.3%), and estimated resting twitch (ERT; TE: 12.5%, ICC: 0.86) all showed very good reliability. TTF also showed good reliability (TE: 17.9%, ICC: 0.92). EMG variables such as MEP/Mmax (TE: 6.5%, ICC: 0.72), SICI (TE: 7.7%, ICC: 0.76), and Mmax (TE: 16.3%, ICC: 0.86) showed good reliability, however CSP duration (TE: 26.1%, ICC: 0.54) reliability was moderate. The post-exercise values for MVC, Qtw.pot, VA and ERT from pre-post exercise also showed good reliability (TEs: 3.5-14.8%, ICCs: 0.75-0.94), whilst EMG variables were less reliable (TEs: 5.6-22.3%, ICCs: 0.37-0.79).

CONCLUSION: Neuromuscular function can be reliably quantified in females taking the OCP. Force-based variables (MVC, Qtw.pot, VA and ERT) presented greater ICCs and smaller TEs than EMG variables (MEP, Mmax, CSP and SICI). However, absolute and relative reliability values are similar to previously published values in males. Thus, these techniques can be used to assess meaningful changes in NMF and fatigability in females. REFERENCE 1. Senefeld, J., et al. Sex Differences in Mechanisms of Recovery after Isometric and Dynamic Fatiguing Tasks. Med Sci Sports Exerc. 2018. In Press.

PIII.48 The Effect of Visual Feedback and Support in the Gluteus Medius Muscle Recruitment During Pelvic Drop Exercise

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Background: The gluteus medius muscle weakness is a disorder that may be related with lower limb pathologies and disorders such as osteoarthritis of the knee and hip joints, patellofemoral pain syndrome and gait disturbance. Pelvic drop exercises are often used to strengthen the gluteus medius in order to increase or prioritize its recruitment. However, the effect of feedbacks and trunk stabilization on the performance of the gluteus medius during pelvic drop exercise is unknown. AIM: To determine the influence of visual feedback and trunk stabilization by support on the recruitment of gluteus medius, tensor fascia latae and quadratus lumborum during pelvic drop adapted exercise.

METHODS: Seventeen healthy subjects (age = 24.4 ± 2.8 years) performed four pelvic drop adapted exercises: Support Group (SP), Mirror Group (MG), Both Group (BG), No Group (NG). The electromyographic activity of the gluteus medius muscle (GM), tensor fascia latae (TFL) and quadratus lumborum (QL) was assessed using surface electromyography. The data were synchronized with an electrogoniometer. For statistical analysis, we extracted the root mean square (RMS) of the upward deflection (movement of hip abduction) for each repetition and expressed as percentage of the MVIC (% MVIC).

RESULTS: Analysis of variance with repeated measures (ANOVA) showed no significant difference on recruiting GM, TFL and QL muscle during the pelvic drop adapted exercises (p=0,78, p=0,82, p=0,38, respectively).

CONCLUSION: Pelvic drop exercise with mirror and/or trunk stabilization did not show significant improvement on the GM, TFL and QL recruitment. Clinical finds of this research showed no effect of visual feedback and trunk stabilization during pelvic drop exercise in the activation of the gluteus medius, tensor fascia latae and quadratus lumborum, which suggests that rehabilitation professionals can perform pelvic drop exercise without the addition of visual feedback and trunk support.

PIII.50 The relativity between quality of double leg circle on the pommel horse and superficial back muscles fatigue trend in gymnastics

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BACKGROUND AND AIM: There are mainly two types of circle system and swing system as the core movements that make up the performance in pommel horse. The circle system is exercised in the horizontal rotation with the supporting posture. Such exercise is also a feature of the pommel horse movement which can't be seen in other events. There is double leg circle (DLC) for basic skill in the circle system. Although DLC is important basis for acquisition of higher difficulty skills, its quality a considerable influence in the E score which evaluates the completeness of the performance. Therefore, the gymnasts are required to perform high-quality DLC throughout the performance, and it is suggested that posture open the shoulder joint angle in the rear support phase is greatly important from previous study[1]. In this study, using the surface EMG, and aimed clarify the training method for sophisticated DLC from relationship between quality of DLC and muscle fatigue trend

METHODS: We instructed 20 university gymnasts to implement DLC 30 times on the two pommels. To evaluate the muscle fatigue tendency acts on rear support posture, middle fibers of the trapezius(MTP), inferior fibers of the trapezius (ITP), latissimus dorsi(LD), posterior deltoid(PDT) were selected. Wireless EMG sensor (SS-WS2901, SPORTS SENSING) were pasted on left and right in muscles. The MPF showing the tendency of muscle fatigue was calculated by performing Fourier transformation using MATLAB R2017a (Math Works) under the condition of a sampling frequency of 1000 Hz, a section length of 500 msec, and a shift length of 20 msec. The trial of the subject was selected as the skilled group(S-group) and the unskilled group(U-group) by the evaluation of the three judges, and compared the muscle fatigue tendency between both groups.

RESULT: During the DLC, the trend fatigue of LD appeared remarkably in all the subjects, and MPF tended to decrease at a constant rate over time. When comparing the S-group and the U-group, the fatigue trend appeared in MTP of the S-group, whereas the U-group tended to keep constant.

CONCLUSION: In the rear support posture during the DLC, the fatigue trend towards of LD appeared remarkably, so it can be said that training to increase endurance is important for continuing performance. On the other hand, the fatigue trend of the MTP of the S-group is presumed to have appeared by being positively mobilized during exercise. MTP is to be acted of adduction the shoulder blades. Therefore, it can be suggested that exercise to protrude the chest and stretch the shoulder joint angle more greatly increases the quality of the DLC. In addition, by implementing training that considers adduction muscles of the shoulder blades, if it can be actively moved, the quality of DLC in the U-group is considered to increase.

REFERENCE: [1]Baudry L et al.(2009): Amplitude variables of circle on the pedagogic pommel horse in gymnastics. Journal of strength and Conditioning Research 23 (3):705-711

PIII.51 Effect of resistance tights on neuromuscular activation of biceps femoris muscle

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BACKGROUND AND AIM: An increase in physical activity during daily living movements is one of the simplest methods of improving and preventing lifestyle-related diseases and age-related muscle dysfunction. Recently, we have attempted to increase physical activity by combining daily living movements, such as walking, with wearing functional tights. The present study aimed to test the effect of wearing tights designed to resist knee flexion movement on neuromuscular activation of the knee flexor muscles.

METHODS: Experiment 1 Eleven males walked on a treadmill while wearing resistance tights, normal tights, and short pants (control). The walking speed was increased from 5 to 7 km/h per minute after a 2-minute warm-up walking at 4 km/h. The resistance tights are designed to resist knee joint flexion based on a construction using different kinds of fabrics for the front and back of the tights (Sixpad training suits, MTG, Japan). During walking, expired gas and surface electromyography (EMG) from the biceps femoris long head (BF) and vastus lateralis (VL) were recorded. Oxygen consumption and the averaged rectified value of surface EMG were calculated for 10 seconds at the end of each walking trial and compared among the three conditions. Experiment 2 Nine males performed knee flexion movement with and without wearing resistance tights. During knee flexion, the knee joint of the right leg was flexed from a fully extended, standing position to 90 degrees for 4 seconds. The knee joint angle was presented with a guideline on a monitor as visual feedback. Surface EMG was recorded from BF and VL muscles of the right leg. Mean averaged rectified values of surface EMG from ten knee flexion movements were compared between the two conditions.

RESULTS: Experiment 1 There were no significant differences in oxygen consumption or surface EMG among the three conditions ($p > 0.05$, Wilcoxon test with Bonferroni correction). Experiment 2 The averaged rectified value of the surface EMG for the biceps femoris was significantly higher with than without the resistance tights ($p < 0.01$, Wilcoxon test). There were no significant differences in averaged rectified values of surface EMG between with and without tights for the vastus lateralis muscle ($p > 0.05$, Wilcoxon test).

CONCLUSIONS: We could not identify any effect of wearing resistance tights during walking. However, there was a significant difference in surface EMG of the BF muscle between with and without resistance tights during simple knee flexion movements. While these results suggest that the resistance tights selectively increased neuromuscular activation of the knee flexor muscles, this effect could be masked during multi-joint movements such as walking.

PIII.52 Contralateral adaptations in rate of force development and rate of muscle activation following unilateral isometric training

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BACKGROUND AND AIM: Unilateral resistance training increases muscle strength of the contralateral homologous muscle group. The cross-education of strength has been observed in healthy and clinical populations, yet improvements in rapid force production and rate of muscle activation are not well documented. The purpose of this study was to examine contralateral adaptations in isometric rate of force development (RFD) and rate of EMG rise (RER) following four weeks of unilateral isometric resistance training.

METHODS: Fourteen healthy volunteers (age: 24 ± 2 years) were randomly assigned to strength training (n = 7, 2 female) or control (n = 7, 2 female) groups. The participants had not engaged in upper body resistance training for at least three months prior to enrollment. The strength training group performed eleven unilateral isometric training sessions of the non-dominant elbow flexors across four weeks. The training intensity was set at 80% MVC for each training session and consisted of five sets of five, five second contractions. The subjects were provided with visual force feedback and were instructed to match their force output as closely as possible to the force tracing. The control group performed the same testing procedures for their dominant elbow flexors as the training group. RFD from 0-50 ms and RER from 0-50 ms were measured before and after the strength training intervention for both the trained and untrained arms. EMG was collected from the biceps brachii with a bipolar surface electrode. Custom LabVIEW software was used to process the data. A three-way (group [training, control] x arm [non-dominant, dominant] x time [pre, post]) mixed factorial repeated measures ANOVA was used to examine the data. The alpha level was set at $p \leq 05$.

RESULTS: The analysis showed no significant ($p = 0.813$, $\eta < 0.01$) three-way interaction. However, there was a significant group x time interaction ($p < 0.01$, $\eta = 0.211$) for RFD ($p < 0.01$, $\eta = 0.174$) and RER ($p = 0.014$, $\eta = 0.120$). Pairwise comparisons revealed that when collapsed across limb for the training group, there were significant increases RFD (192.1%, $p < 0.01$), and RER (126.6%, $p < 0.01$) post-training. A follow up linear regression showed that the changes in RER accounted for 56% (R2 = 0.562) of the variance in changes for RFD of the untrained arm. There were no significant changes for any of the variables in the control group.

CONCLUSIONS: This data indicates that the increases in RFD (Percent change: 183.3%, 209.1%) and RER (Percent change: 162.9%, 102.2%) were not significantly different between trained and untrained arms, respectively. Importantly, these observations suggest the training-induced improvements in rate of force development for the untrained arm were due to neural adaptations (i.e., rate of activation).

PIII.53 The relativity between pedaling characteristics and both EMG aspect and muscle fatigue

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Introduction: In Cycling performance, since not all pedaling force can be used on rotating crank, it's important to make pedaling force as efficiently as possible. Pedaling efficiency, which is an index indicating the ratio of effective pedaling force to all pedaling force, has been proposed and used to assess the pedaling skill1). According to the Internet and magazines, some techniques are introduced as the way to increase this index and are mainly classified into two types: one focuses on increasing tangential direction force (Circle Pedaling: CP), and the other one focuses on increasing vertical direction force (Vertical Pedaling: VP). As those two techniques are widely known, it is considered that pedaling characteristics of cyclists are also classified into two types. In this study, we compared the EMG aspect and muscle fatigue during cycle exercise of different group classified according to pedaling characteristics has.

METHODS: Twelve male cyclists participated in this study and were divided into two groups: CP and VP. After attaching measure equipment, subjects carried out following protocol: worming up (3 min, 60% main exercise load, about 90 rpm), main exercise (5.5 min, 4.5W/kg, 100 rpm), rest, Maximum Voluntary Contraction (MVC) measurement using cycle ergometer whose size was copied from each subject's road bike. We extracted activation section from EMG in seven lower limbs muscles using knee joint angles and calculated the Root Mean Square (RMS), %MVC and Mean Power Frequency (MPF). The muscular active mass and muscle fatigue were estimated from %MVC and MPF.

RESULTS: By comparing the muscular active mass, there were no significant differences between two groups in each type of muscle. And there were also no significant differences between muscles in different groups. By comparing the MPF decreasing rates in each muscle, CP on vastus medialis muscle and VP on gastrocnemius muscle showed significant ($P<0.01$) reduction.

CONCLUSION: Results of this study suggested that muscle fatigue arising in CP on vastus medialis and VP on gastrocnemius is larger than opposite group. These results indicated that the classification based on pedaling force direction can offer the priority order when cyclists build up muscular endurance or make recovery care after the training or the competition.

Reference: 1)Davis,R.R. and Hull,M.L. Measurement of pedal loading in bicycling:?U. Analysis and results, J.Biomechanics, 14(12), 857-872, 1981

PIII.54 Knee Stabilization Strategies in ACL-Injured and ACL-Reconstructed Individuals in Response to Soccer-Specific Loading: A Preliminary Investigation.

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INTRODUCTION: Most of non-contact ACL-injuries and re-injuries occur during sport-related movements as landings and side-cuttings. The dynamic stabilization of the knee joint, together with the passive restraint to anterior tibial translation (ATT) provided by the ACL, are crucial for reducing the risk of injury. It has been reported that ATT may raise of 20-30% in response to exercise, which leads to altered landing biomechanics. In addition, individuals who suffered from an ACL tear showed muscle pre-activation imbalances between knee extensors and flexors prior to injury (1). The aim of this study was to examine the effect of soccer-specific loading on knee stabilization strategies in ACL-R, ACL-I and healthy (ACL-H) soccer players.

Methods: One ACL-R (height: 1.77 m; body mass: 75kg), 1 ACL-I (height: 1.74 m; body mass: 71kg) and 1 ACL-H (height: 1.76 m; body mass: 70kg) competitive soccer players volunteered in this investigation. A 45-min version of the Soccer Aerobic Field Test (SAFT45) was used to simulate the mechanical and physiological demands of half soccer-match. ATT as well as Vastus Lateralis (VL), Vastus Medialis (VM), Semitendinosus (ST) and Biceps Femoris (BF) EMG amplitudes during single-leg drop landing (SLDL), were recorded in both legs prior and after SAFT45 protocol. EMG activations in the 100ms before ground contact was obtained and the difference in percentage between PRE- and POST-SAFT45 in ATT and muscle pre-activities was calculated.

RESULTS: ATT in ACL-H and in the operated leg of ACL-R was unchanged after SAFT45, whereas ATT of the injured leg of the ACL-I and the healthy leg of ACL-R considerably increased (+28%). Prior to SAFT45, VL pre-activity of the healthy and operated leg of ACL-R was higher than ST (+11.7% and +17.2%, respectively), whereas ACL-H showed lower VL pre-activity than ST (-14%). After SAFT45 VL pre-activity of the ACL-R operated leg was 21.6% higher than ST, whereas no difference between VL and ST pre-activation was found in ACL-H. VL pre-activity in the reconstructed leg was higher than VM both before (+13.7%) and after (21.2%) SAFT45. In contrast, ACL-H showed lower VL pre-activity than VM before SAFT45 (-13%) and no difference after SAFT45. ACL-I showed no differences among muscle pre-activations.

CONCLUSION The ACL reconstructed soccer player showed altered knee stabilization strategies predisposing to ACL injury (1), which tend to be more prominent after loading.

1. Zebis, et al. Am J Sports Med 2009; 37(10), 1967-1973.

PIII.55 Does it Count if You Can't Count it? Using Multiple Research Methods to Prepare Kinesiology Practitioners

Sean P Sullivan
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Research methods and designs in the sport science literature continue to diversify. While quantitative methods have established much of the theoretical foundation of our discipline, qualitative methods have increased in the past decade as viable and systematic processes for contributing to the field. Methodologic and professional issues are being discussed related to these diverse empirical strategies, and an increasing amount of the sports science literature supports both approaches. It is worth examining the educational implications of these differing methods for preparing graduate students and future Kinesiology practitioners. The present study examined 25 graduate sports science students enrolled in a ten-week research methods course. A phenomenological approach was used to collect data from 25 students using in-depth interview methods. A constant comparative analysis approach was used to identify common themes from the transcript data.

RESULTS involve data themes that can benefit those interested in improving the educational preparation of future sports science practitioners.

PIII.56 Evaluating Balance, Cognition, Ocular Motor Function & Patient Reported Symptoms to Guide Return to Play after Concussion

Jeff A Sullivan, Rachel Le
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Background and Aim: Sport related concussion (SRC) is the most common type of brain injury in young people. The current best practice for concussion assessment incorporates multiple tools to determine patient symptoms, cognition, balance and neurological status. However, these tools present challenges for healthcare professionals; their clinical usefulness is largely undefined, and symptoms and recovery are variable among concussed patients. We evaluated balance (using a novel BTrackS Balance Tracking System), Vestibular Ocular/Motor function (via the VOMS tool), cognition (via the SCAT-3) and patient-reported symptoms (via the PCSS form) in subjects who sustained a SRC.

METHODS: We evaluated 9 intercollegiate athletes (5 women, 4 men; 21 ± 2 yrs) using the four tools at baseline and/or within 24 hours, 48 hours and 72 hours after injury.

RESULTS: Mean Vestibular Ocular/Motor function was significantly decreased at 24 hours after injury (p(2,7)=.008) and improved significantly at 48 hours after injury (1.2 ± 1.4 symptoms at 24 hrs versus 0.33 ± .71 at 48 hrs; p(1,8)=.021). Balance deficits were also evident between baseline and 24 hrs after injury (23.4 ± 6.8 versus 21.0 ± 4.2), although not statistically significant (p=.39, d=.45). Subjects reported 7 symptoms on average on the SCAT-3 after injury, with cognition scores then improving progressively over time (24hrs = 54.0 ± 15.9 versus 48 hrs = 39.3 ± 13.6 versus 72 hrs = 36.2 ± 11.4) although not statistically significant (p(2,7)=.17, d=1.2). Ocular/Motor function (i.e. VOMS scores) and balance (i.e. BTrackSTM scores) were significantly correlated at 24 hrs (r=.72; p=.027) and 48 hrs after injury (r=.85; p=.031). SCAT-3 cognition scores were not significantly correlated to VOMS (r= -.07 to .45) or BTrackS scores (r= .09 to .65).

CONCLUSION: These results suggest the VOMS and BTrackS tools may provide more useful data to clinicians than traditional tools (i.e. SCAT-3) to assess and manage SRC. This research was supported in part by the American Council on Exercise.

REHABILITATION/REHABILITATION TECHNOLOGIES

PIII.57 Relationship between muscle swelling immediately after resistance training and muscle hypertrophy after 6-week intervention

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BACKGROUND AND AIM: Immediately after resistance training, muscle swelling occurs due to increased blood flow and accumulated metabolic materials. Muscle swelling has been recognized to be an important factor for promoting muscle hypertrophy. However, it is unknown whether the degree of muscle swelling is associated with muscle hypertrophy. Muscle hypertrophy is obtained after several weeks of intervention. Therefore, we assumed that identifying the degree of muscle swelling needed to induce muscle hypertrophy might be a useful indicator for predicting long-term effects of muscle hypertrophy. Thus, the purpose of this study was to investigate relationship between muscle swelling immediately after resistance training and muscle hypertrophy after 6-week intervention.

METHODS: Twenty-two healthy young men performed resistance training for knee extension consisting of 3 sets with 8 repetitions at a load of 80% of 1RM. Muscle thickness of quadriceps femoris was measured using B-mode ultrasound-imaging device. The increase of muscle thickness immediately after a bout of training sessions was used as an indicator of muscle swelling. In addition, the increase of muscle thickness after 6-week intervention was used as an indicator of muscle hypertrophy. Muscle thickness was measured at three anatomical sites (proximal, medial and distal sites) of front (rectus femoris and vastus intermedius), lateral (vastus lateralis and vastus intermedius) and medial (vastus medialis) part of femur, respectively. The sum of the 9 measurements was used for analysis. Paired t-tests were used to determine the change in muscle thickness immediately after a bout of training sessions and the change in muscle thickness after 6-week intervention. Pearson's coefficient correlation was used to analyze relationship between the change in muscle thickness immediately after a bout of training sessions (muscle swelling) and the change in muscle thickness after 6-week intervention (muscle hypertrophy).

RESULTS: Paired t-tests revealed that muscle thickness significantly increased after a bout of sessions (percent change; 8.3±3.2%) and that muscle thickness also significantly increased after 6-week intervention (percent change; 2.9±2.6%). There was a significant correlation between the increase in muscle thickness after a bout of training sessions and the increase in muscle thickness after 6-week intervention ($r=0.441$).

CONCLUSIONS: The results showed that high-intensity resistance training at 80% of 1RM could cause muscle swelling, and could induce muscle hypertrophy after 6-week intervention. In addition, our result showed a correlation between muscle swelling and muscle hypertrophy. These results suggest a possibility that the degree of muscle swelling could be a useful indicator to predict muscle hypertrophy due to intervention.

PIII.58 Coupling robotic tasks and surface electromyography to assess muscle fatigue in children with neuromuscular diseases

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[1]Istituto Italiano di Tecnologia, [2]Istituto Giannina Gaslini

BACKGROUND AND AIM: Neuromuscular disorders (NMD) is a broad term encompassing many diseases that impair the functions of skeletal muscles. Despite being widely different from clinical and physiological perspectives, NMD share fatigue as a common and highly debilitating symptom. Its assessment might provide crucial information on the disease, on its progression and on the efficacy of the potential therapy. Although for Duchenne muscular dystrophy (DMD) a variety of therapeutic strategies are currently being investigated, with an increasing number of available pharmaco-gene therapies, an objective and effective tool to properly measure muscle fatigue is still missing. Indeed, conventional methods used to evaluate motor functions and strength do not provide any quantitative information about it. The only clinical scale targeting muscle fatigue is the 6-minute walk test (6MWT) that can only be used in ambulant patients, excluding therefore a large part of the neuromuscular population. Questionnaires, such as Multidimensional Fatigue Inventory (MFI) and the Fatigue Severity Scale (FSS), are standard tools to evaluate muscle fatigue, but they lack in reliability, objectivity and are not sufficient for a detailed characterization of the disease. On the other hand, there are other procedures to assess muscle fatigue, based on surface electromyography (sEMG). These techniques, however, require the acquisition of the Maximum Voluntary Contraction or are based on high fatiguing tasks which cannot be sustained by pediatric NMD population. In order to overcome such drawbacks, while exploiting the potential of sEMG analysis, we propose a fast test which couples a robotic task to sEMG parameters. This novel method allows the extraction of an objective indicator of fatigue based on the Mean frequency of the sEMG signal.

METHODS: The test is a simple reaching task consisting on flexion-extension movements of the wrist performed with Wristbot, a three degrees of freedom robotic device designed for motor control studies and rehabilitation of the human wrist. sEMG signals of right flexor and extensor carpi radialis muscles were recorded throughout the test. Mean frequency of the sEMG signals was calculated to obtain the Onset of fatigue indicator (OF). In this study five children with DMD performed the test.

RESULTS: The experiments validated the reliability of the OF indicator which thus has proven to provide a precise and easily readable value of muscle fatigue. All subjects successfully performed the test and their OF was calculated showing early fatigability as expected.

CONCLUSIONS: This work proves the feasibility of the proposed method on neuromuscular subjects and in particular on the pediatric ones. Thanks to its proved repeatability, obtained by the use of a robotic task, and the minimum time required to be performed, the test can be repeated regularly to objectively monitor the progression of the disease or to support clinical trials for new therapies.

PIII.59 Muscle Contraction Evaluation during Recumbent bicycle Pedaling by using the MMG/EMG Hybrid Transducer System

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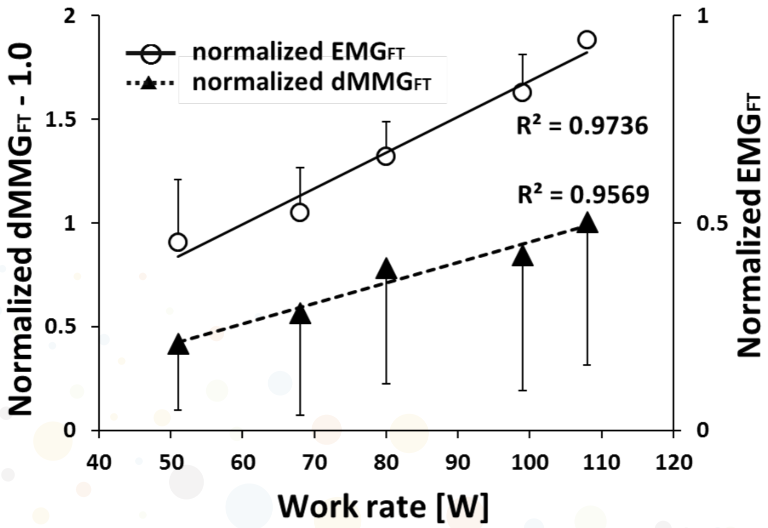
BACKGROUND AND AIM : Electromyogram (EMG) records an electrical signal for muscle contraction, but mechanomyogram (MMG) reflects mechanical behavior of muscle contraction. By simultaneous measurement of both signals, it is possible to evaluate muscle contraction accurately. MMG measurement and record was difficult under voluntary movement because of the use of accelerometer as the MMG transducer. The authors developed the MMG/EMG hybrid transducer system which was capable of simultaneous measurement of displacement MMG (dMMG) and surface EMG and applied it to muscle contraction evaluation of dynamic exercise during recumbent bicycle pedaling.

Methods: Four healthy male volunteers (age: 25.5±7.0) participated in this study. The MMG/EMG hybrid transducer was attached to the surface of vastus medialis (VM) muscle of their right legs, which was fixed with a restriction belt. The subjects were seated on a recumbent bicycle (C545R, SportsArt, USA) and pedaled at 60 rpm. When the pedaling velocity of subject became constant, the measurement of MMG/EMG was performed for ten seconds. The pedaling of recumbent bicycle were performed with five working rate of 51, 68, 80, 99 and 108 W, and additional passive pedaling (the other volunteer rotated the pedals while the subject was not exerting their muscle strength). Each pedaling load was measured four times and the power spectra of MMG/EMG waveforms of typical three cycles were obtained and the total power (area value) below 100 Hz was calculated, respectively (dMMGFT and EMGFT). This experiment was performed with approval of the ethic committee of Okayama University.

RESULTS: Figure shows the relationship between work rate and the normalized EMGFT and normalized dMMGFT. Both of them continued to increase with increasing work rate That is, the dMMGFT and EMGFT increased as the muscle strength increased. The normalized dMMGFT, an indicator of muscle strength, was calculated based on the dMMGFT generated by passive pedaling and the normalized EMGFT was calculated by the maximum value as the reference. The normalized dMMGFT and normalized EMGFT were linearly approximated and had a strong correlation with the work rate. The difference in the correlation among subjects may indicate the presence/absence of reserve power of muscular strength in the pedaling load.

CONCLUSIONS: The MMG and EMG obtained by this system provided evidence that muscle strength can be evaluated even during dynamic exercise and the MMG / EMG hybrid transducer system with excellent versatility may be a powerful tool for the evaluation of muscle contraction during dynamic exercise.

ACKNOWLEDGEMENT: This research was partially supported by a Grant-in-aids for Scientific Research (17K01360) from Japan Society for the Promotion of Science.


normalized EMGFT
normalized dMMGFT
R² = 0.9736
R² = 0.9569
Normalized dMMGFT - 1.0
Normalized EMGFT
Work rate [W]
2
1.5
1
0.5
0
40
50
60
70
80
90
100
110
120

PIII.60 Ulnar nerve Conduction Block Using Surface Kilohertz Frequency Alternating Current- A Feasibility Study

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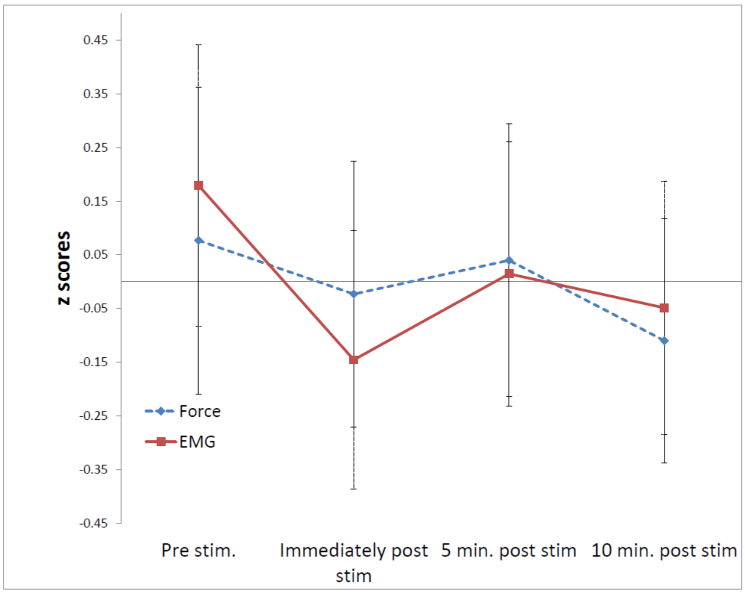
[1]Ariel University Israel, [2]Spotlight technologies

BACKGROUND AND AIM: The aim of this study was to test the effects of kilohertz frequency alternating current (KHFAC) surface stimulation applied to the ulnar nerve on force and myoelectrical activity of the abductor digiti minimi (ADM) muscle.

METHODS: Eighteen healthy volunteers (age- 27.6±7.9 years; 10 males, 8 females) included in the study. Each subject participated in one session during which a biphasic 7kHz rectangular pulse was delivered above the medial epicondyle of the humerus to induce ulnar nerve blocking. ADM electromyographic (EMG) activity and contraction force were measured before (Pre), immediately after, and following 5 and 10 minutes post stimulation (post 1, post 2).

RESULTS: The results showed that EMG activity decreased immediately after stimulation compared to pre stimulation, it returned to the level of pre stimulation at 5 minutes (post 1), and decreased again at 10 minutes (post 2). Furthermore, analysis of compound adjusted z-score indicated significant decrease of force and myoelectrical activity immediately, and 10 minutes post stimulation (Figure 1).

CONCLUSIONS: The findings, which demonstrate that KHFAC surface stimulation of the ulnar nerve may decrease the motor activity of intrinsic hand muscle, can help to develop future methods of neuromodulation to treat hand spasticity.



PIII.61 Evaluation of Achilles Tendon Stiffness During Contraction: A Comparison Of Different Sonoelastography

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AIM: The aim of this study was to evaluate differences in stiffness of Achilles tendon during contraction measured with different sonoelastography devices

METHODS: Twenty healthy subject were recruited. Longitudinal sonoelastography images of the left and right Achilles tendon area were acquired with four different ultrasound devices, two strain sonoelastography (Mindray, Toshiba) and two shear wave elastography (Mindray, Supersonic) Achilles tendon of the participants were analysed under different contraction levels in plantar flexion using an ankle ergometer with visual feedback at: 0 kg, 0.5kg, 1 kg, 2 kg, 5 kg and, 10 kg. An external reference material (Zerdine®, CIRS, Inc., Norfolk), with known elastic properties was placed on the subject's Achilles tendon and included in the b-mode scans for the strain elastography analysis. The external reference material was used to provide a comparison between the examined tissue and a material in which a constant elasticity was present. The range between soft and hard (from red to blue) was divided in 256 steps (0-255), according to the ultrasound image color depth. The median and interquartile range of colors was computed. Strain ratio (Tendon/Reference) were calculated Shear wave images were analysed on the ultrasound device, a region of interest (ROI) was drawn in the tendon and shear elastic modulus (kPa) were extracted. Non parametric test (Friedman test) was used to compare stiffness difference during contraction for each of the ultrasound device.

RESULTS: Strain ratios and elasticity (kPa) values at difference contraction level are summarized in the figure. Mindray strain sonoelastography show a decrease tendon elasticity (increase stiffness) during contraction from 1.46±0.64 to 0.35±0.13. Toshiba strain sonoelastography show a decrease tendon elasticity (increase stiffness) from 1.20±0.67 to 0.55±0.20. Mindray shear wave elastography show a decrease stiffness during contraction from 37.34±16.14 kPa to 16.14±2.75 kPa. Supersonic shear wave elastography show an increase stiffness between the first two contraction levels from 410.4±103.8 kPa to 479.8±75.1 kPa and a decreased stiffness for the higher contraction levels from 442.8±103.7 kPa to 294.2±64.4 kPa.

CONCLUSION: Strain elastography with reference material is a technology able to intercept stiffness changes between the different contraction level on the other hand shear wave elastography seems to have technical problem when Achilles tendon is under load. Incoherence between the results of the two technologies should be further investigated.

ACKNOWLEDGEMENT: We thank the staff and students of the Policlinico San Matteo for participating in the study.

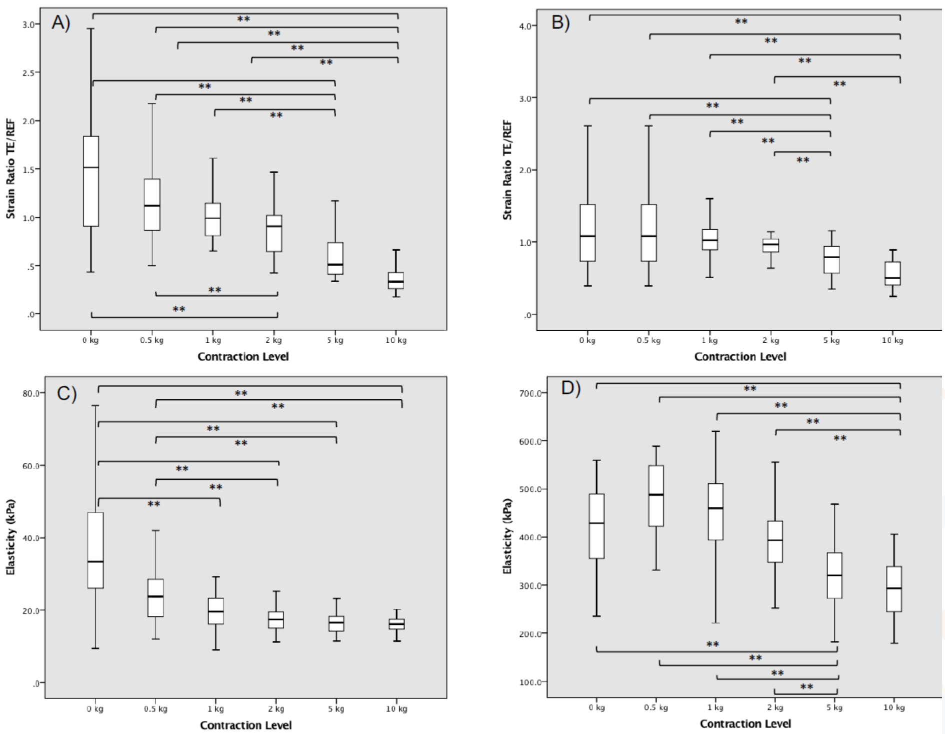

Figure 1. Figure show the box plots for the four different technologies: A) Mindray strain elastography; B) Toshiba strain elastography; C)Mindray shear wave elastography; D) Supersonic shear wave elastography.

** $p<0.05$; statistical significant difference between the different contraction levels

PIII.62 The Visual Contribution To Postural Control During Visual Feedback-Based Tasks

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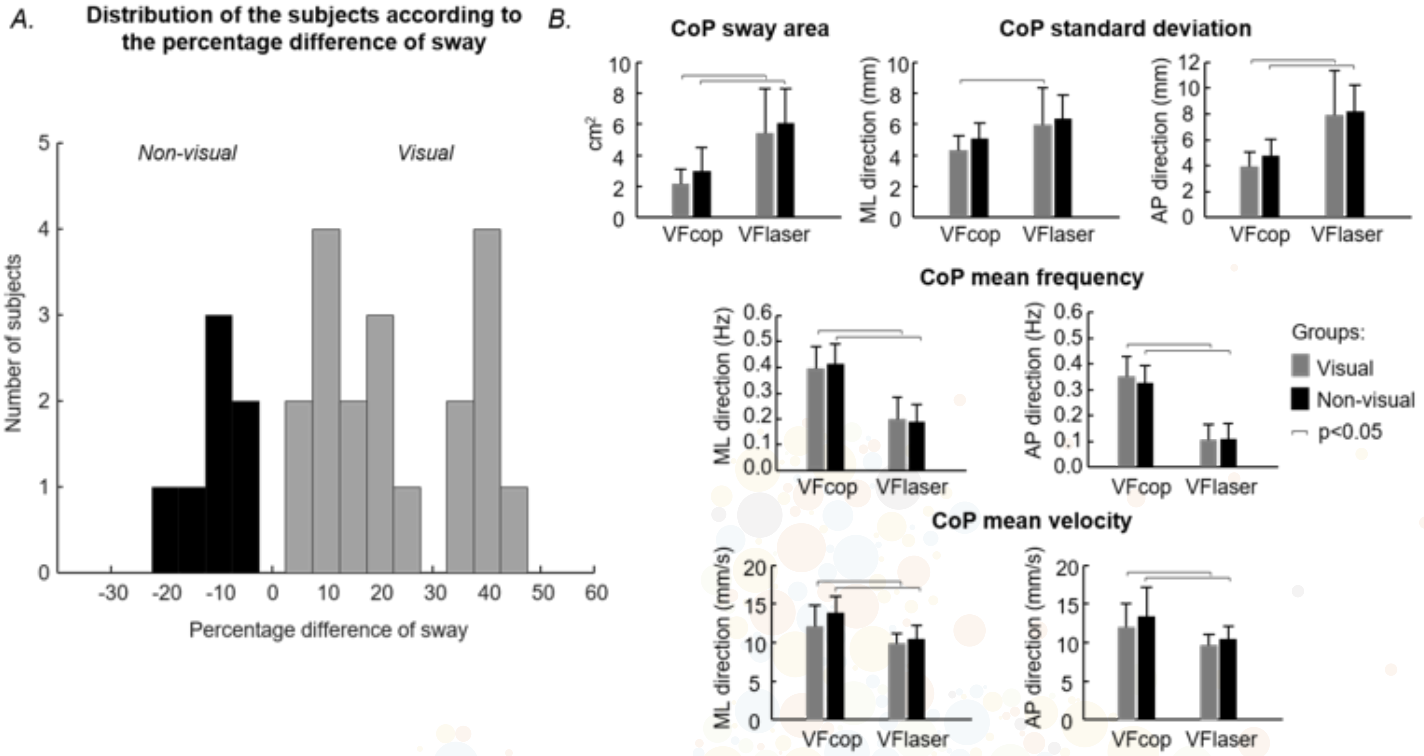
BACKGROUND AND AIM: It is well-documented that visual feedback-based motor tasks lead to alterations in the control of postural sway during standing balance. However, we wished further the understanding about whether the visual feedback affects similarly postural sway in individuals who relying heavily on vision or not during the postural control.

METHODS: Twenty-six subjects volunteered for this study. They were asked to stand barefoot comfortably on a force plate with their arms alongside the body and: 1) maintain the eyes open (EO); 2) maintain the eyes closed (EC); 3) control their centre of pressure (COP) position as close as possible to a target from the visualization of COP signal (VFcop); 4) control the position of laser pointer with their right hand as close as possible to the same target used previously (VFlaser). The quantification of COP displacements was estimated from the ground reaction forces and moments acquired through a force-plate (AccuSwayPLUS, AMTI, Watertown, USA) during 60 seconds in each condition. In addition, the following stabilometric parameters were computed: COP sway area, standard deviation, mean velocity and mean frequency in the antero-posterior (AP) and medio-lateral (ML) directions. The index based on percentage difference of COP sway area, as evaluated by the ratio [(EC area-EO area)/(EC area+EO area)×100], was used to split subjects in two subgroups, relying heavily on vision (visual) or not (non-visual; Figure 1A). A two-way analysis of variance (ANOVA) for repeated measures was used to compare the stabilometric parameters, with one between factor (group) and one within factor (tasks); post hoc comparisons were made with the Tukey HSD test (significance level of 5%).

RESULTS: A main effect of task was revealed ($p<0.01$ in all cases) while a main effect of group was not observed for stabilometric parameters ($p>0.19$ in all cases) and no significant interactions were found ($p>0.20$ in all cases). Regardless of group, COP sway area and standard deviation were significantly smaller in VFcop than VFlaser, except for standard deviation (ML; Figure 1B). Mean frequency and mean velocity were significantly higher in VFcop than VFlaser in both directions (Figure 1B).

CONCLUSIONS: Our results suggest the degree of visual dependence to postural control does not seems to influence the effect of different visual feedback tasks. In both groups (visual and non-visual), the visual feedback condition affected similarly postural sway. Therefore, visual feedback was effective enough to change postural sway even in those subjects who do not depend heavily on visual information for control of standing balance, with potential implications for the training of postural control from visual feedback protocols. Figure 1. (A) histogram distribution according to percentage difference of sway. (B) stabilometric parameters in the antero-posterior (AP) and medio-lateral (ML) directions for the VFcop and VFlaser conditions. Bars represent the averaged results across participants and error bar, the standard deviation.


A.
Distribution of the subjects according to the percentage difference of sway
Non-visual
Visual
Number of subjects
Percentage difference of sway
B.
CoP sway area
cm²
CoP standard deviation
ML direction (mm)
AP direction (mm)
CoP mean frequency
ML direction (Hz)
AP direction (Hz)
CoP mean velocity
ML direction (mm/s)
AP direction (mm/s)
VFcop
VFlaser
Groups:
Visual
Non-visual
p<0.05

PIII.63 Scan-To-Knit - A platform for personalised smart textiles research and development with a special focus on prosthetics

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University of Borås

BACKGROUND AND AIM: In Sweden, approximately 3000 people are amputated every year; about 90 % of which cases are amputees of the lower extremities and about 10 % of the upper limbs. When a person becomes a limb amputee, he or she requires a prosthetic device(s) and services, which become a life-long event. Apart from restoring function, usability and comfort issues are crucial qualities of a prosthetic device. The simple truth is that if the prosthesis is uncomfortable, the person is not going to wear it. Smart textiles are defined as textiles that can sense, react and adapt to environmental stimuli through the integration of functionalities in textile structures. As smart textile -based solutions enable the design and production of wearable functional products with minimal discomfort for the user, the last decade has seen a number of health/healthcare applications based on smart textiles. Research has demonstrated that e.g. electrophysiological signals such as electromyogram (EMG), electrocardiogram (ECG), electroencephalography (EEG), and respiratory signals can be monitored using textile-based sensors. The objective of this project is to investigate methods that contribute the missing links that enable the development of personalised smart textile solutions for prosthetic limb users with an emphasis on improving user comfort while also enable e.g. EMG electrodes to be integrated in the personalised textile. The overarching research question addressed is: How can smart textiles and new textile production techniques be utilized to address common usability issues in prosthetics?

METHODS: The current project Scan-to-Knit address the objective by focussing on establishing a technology platform that contributes the missing links for the development of personalised textile solutions for amputees including a) 3D scanning of stump volumetric data; b) Creating a 3D geometric model of the stump with additional functionality; c) generating a knitting pattern based on the 3D scanning; d) producing the personalised textile in a computerized flat knitting machine (see figure 1).

RESULTS: At this early stage in the project, 3D scanning data of two volunteers have been collected using Humans Solution 3D Body scanner. The volumetric data has been manually transferred to a flat knitting machine and two prototypes have been made. Preliminary results show that the knitted textile electrodes can be used for acquiring sEMG signals. The Scan-to-Knit technology platform allows easy production of individualised textiles with integrated electrodes at the proper location, which gives the best possible signal acquisition result at the same time improving the comfort for the users.

CONCLUSIONS: The combination of smart textiles and the new textile production technology platform enables the design and production of an individualised functional textile including EMG electrodes interfacing the amputated limb and the socket of the prosthetic device. In addition to the customisation/personalisation of textile products, the platform also, when fully utilized, has the potential to reduce the lead-time of the customisation, and to lessen the cost for individualized textile solutions focusing wearability and comfort for prosthetic device users.

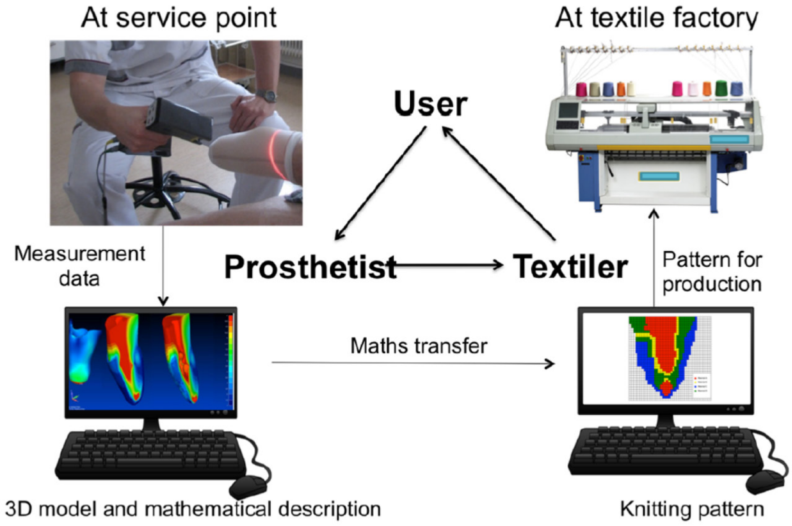

Figure 1. Illustration of the technology platform 'Scan-to-Knit' formulated by the University of Borås together with industrial partners Bola AB (textile manufacturer), Integrum AB, and Lindhe Extend AB (prosthetics). The Scan-to-Knit project is funded by the Swedish Knowledge Foundation.

PIII.64 Characteristics of writing for persons with Essential tremor and with Parkinsonism tremor and the effect of the restraint appliance (Palm Supporter)

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The University of Electro-Communications

Patients with essential tremor and Parkinsonism tremor always encounter difficulties to write letters due to their hand tremble in wide range. Tool to control their hands during writing has been desired for long time. Palm supporter shown to control the hand was designed in our study. In the study the effect of the palm supporter is studied. Palm supporter is made of copper wire covered with vinyl. The palm supporter is attached to back of a hand when the patients write letters in Fig.1. Four kinds of writing letters are used: That is, horizontal line, vertical line, circle, and Chinese word with three letters are carried out. The method of writing is as follows: At the first time the subject writes ten times of one kind of writing letters without palm supporter and in next time the subject writes same writing letters with use of palm supporter. In order to measure the movement of the hand during writing, the sensor with three dimensional accelerations is set on the back of hand. The data measured by the sensor with a built-in transmitter is send to personal computer in wireless system.

The sensor detects hand's movement of acceleration during writing. The writing is carried out for four kinds of letters. To make comparison with movement of hand during writing, the movement of hand holding pen without writing is also measured as the rest state of hand. The data of the accelerations measured are calculated by Fourier transform, and the power spectrum is evaluated. The power spectra for respective directions as X, Y, and Z are summed up in the range from 1Hz to 50Hz. The values of X, Y, and Z are evaluated as total power. Moreover, the total value for three dimensions is evaluated as term SQRT (XYZ) where SQRT (XYZ) = (X2+Y2+Z2)(1/2) in the unit of G2, where G is acceleration of gravity. Two kinds of patients which are six patients with essential tremor and eight patients with Parkinson's tremor are measured in advanced age (average 75 years old). These results value of SQRT (XYZ) both with use of palm supporter and without palm supporter are obtained. The results denote that the values of SQRT (XYZ) with palm supporter are smaller than that without palm supporter for four kinds of letters. Consequently the effect on control to shivering during writing is shown with use of palm supporter.

Fig. 1. Palm supporter and Sensor (Acceleration) are stuck on back of hand

PIII.65 Dexterous Prosthesis and Structured Training Can Reduce Compensatory Movements in Upper-Limb Amputees

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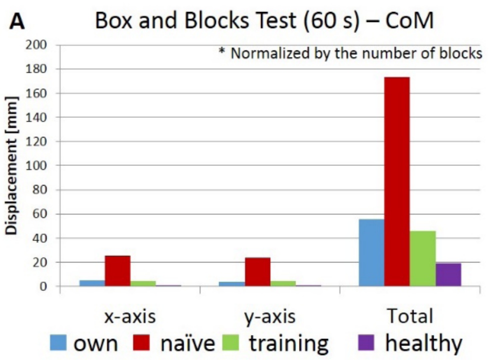
Following the loss of a limb, new myoelectric prosthetic users tend to develop a set of compensatory strategies in order to accommodate for missing degrees of freedom (DoFs) while performing daily activities. In time, these can lead to overuse of supporting anatomical structures and consequently result in chronic pain. Here, we investigated the full body compensations expressed by an experienced transradial myoelectric prosthesis user. We observed the displacement of the centre of mass (CoM) during the execution of two standard clinical assessment tests. The subject was asked to complete the clothes pin relocation test (CPRT) and box and blocks test (BBT) using a commercial single DoF myoelectric prosthesis that she had been using for over 20 years. In addition, we have provided the subject with an advanced prosthetic hand with active rotation and flexion/extension units, and two grip types. Using this new device, in two separate sessions, the patient completed the same clinical tests as with the commercial prosthetic system, immediately after receiving the new system and following a period of targeted structure rehabilitation prosthetic training. The patient was able to transfer 21 blocks using her own prosthesis, and only 3 when fitted for the first time with the advanced system. However, following training, the patient transferred 15 blocks with the advanced system. Similarly, the patient could relocate 3 clothes pins in 26.75 s using her prosthesis and did the same task in 62.06 s before and in 31.69 s after training with the advanced system.

RESULTS: shown in the panel A of the figure indicate an increased body compensation in the naïve advanced prosthetic session during the BBT, followed by a substantial decrease after the training. The CoM trace spread during the CPRT decreased with the introduction of the advanced prosthesis, particularly following training (panel C). At this stage, the observed CoM trace was similar to that observed in an able-bodied control subject. These preliminary results indicate that given the multi-articulated prosthesis, patients require training in order to match the performance of their own long-term devices. However, the effects of additionally available DoFs have an immediate impact on the reduction in unwanted full body compensatory movements.



B Clinical Scores

	own	naïve	follow up
BBT [blocks]	21	3	15
CPRT [s]	26.75	62.06	31.69

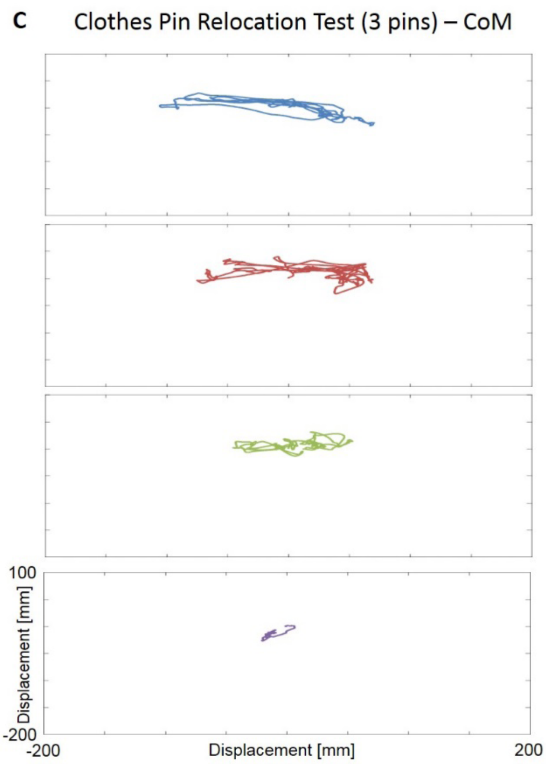


Figure – Results of Box and Blocks (BBT) and Clothes Pin Relocation Tests (CPRT) observed in a transradial myoelectric prosthesis user and a healthy control. **(A)** Normalized center of mass (CoM) displacements during BBT while using own commercial prosthetic (blue), first time upon receiving the advanced system (red) and following the structured training protocol (green). Healthy control (purple) is used as a reference. **(B)** Clinical scores for both CPRT and BBT. **(C)** Spatial displacements of CoM during CPRT in the all four aforementioned cases

PIII.66 Relationship between muscle architecture and functional capacity in older adults

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[1]University of Jaén, [2]University of Málaga

AIM: to investigate the associations between functional capacity, ultrasound-measured rectus femoris muscle thickness and anthropometrics in a population of institutionalized older adults.

METHODS: 12 older adults (9 women and 3 men, mean age ± SD: 86 ± 7 years, body mass index: 24 ± 3 kg/m2) participated in this cross-sectional study. Functional capacity was assessed using five repetition sit to stand test. Rectus femoris muscle thickness in repose and in maximum voluntary contraction (MVC) using B-mode ultrasonography and anthropometrics were measured (weight, height and mid-arm circumference). Muscle images were analysed offline with ImageJ software. Two longitudinal images in repose and MVC were measured and averaged. The relationships of the variables were analysed using Pearson correlation coefficient and multiple linear regression analysis.

RESULTS: significant bivariate correlations were found between sit to stand test and rectus femoris muscle thickness in MVC ($r=-0.755$, $p=0.005$) and repose (-0.586, $p=0.045$). Multiple linear regression analysis showed associations between sit to stand test and muscle thickness, after adjusting by arm circumference and body mass index. The independent variables explained about 88% of variance in the 5STS test ($R2 = 0.877$, $p = <0.001$).

CONCLUSIONS: rectus femoris muscle thickness measured with ultrasonography, BMI and mid-upper arm circumference could explain a high percentage of the variability of functional capacity in institutionalized older adults measured by five repetition sit to stand test.