International Society of
Electrophysiology and Kinesiology

June 22 – 25, 2022
Québec City, Canada

abstract book

ISEK XXIV

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Symposium Abstracts

Thursday June 23, 2022

Symposium 1 – Aging and central nervous system “Quantification of invisible changes in aged-human body”

S1.1 Effects of aging on persistent inward currents of human motoneurons

Gregory Pearcey[1], Altamash Hassan[1], Melissa Fajardo[1], Mark Cummings[1], Francesco Negro[2], Laura Miller McPerson[3], Julius Dewald[1], CJ Heckman[1]
[1]Northwestern University, [2]Università degli Studi di Brescia, [3]Washington University in St. Louis

BACKGROUND AND AIM: Aging is a natural process that causes alterations in the neuromuscular system, which contribute to weakness and reduced quality of life. Reduced rates of motor unit (MU) discharge likely contribute to weakness, but the mechanisms underlying reduced discharge rates are not clear. Persistent inward currents (PICs) are crucial for the initiation, gain control, and maintenance of motoneuron discharge, and are directly proportional to the level of monoaminergic input. Since the concentration of monoamines (i.e. serotonin and norepinephrine) are reduced with age, we sought to determine if estimates of PICs are reduced in older (>60 years old) compared to younger adults (<35 years old). METHODS: We decomposed MU spike trains from high-density surface electromyography over the biceps brachii and triceps brachii during isometric ramp contractions to 20% of maximum. Estimates of PICs (i.e. ΔF) were computed using the paired MU analysis technique and compared between younger (18-35 years) and older (>60 years) groups of adults. RESULTS: Regardless of the muscle, peak discharge rates of older adults were reduced by ~1.6 pulses per second (pps) ($P = 0.0292$), and ΔF was reduced by ~1.9 pps ($P < 0.0001$), compared to younger adults. We further found that age predicted ΔF in older adults ($P = 0.0261$), resulting in a reduction of ~1pps per decade, but there was no relationship in younger adults ($P = 0.9637$). CONCLUSIONS: These findings suggest that PICs are reduced in older adults, and that age is a significant predictor of estimates of PICs in older adults. Reduced PIC magnitude represents one plausible mechanism for reduced discharge rates, weakness, and reduced function in older individuals.

S1.2 Motor unit activation properties in older adults and stroke patients

Allison Hyngstrom[1]
[1]Marquette University

This presentation will highlight potential neural mechanisms of reduced force steadiness seen with aging and older clinical populations. In addition to declines in maximal voluntary strength, it is known that older adults are less steady in force output during isometric contractions compared with younger adults. Often, activities of daily living require dual tasking involving a cognitive challenge that is not automated while performing a submaximal motor task. Age-related cognitive function declines can interfere with the ability of older adults to dual task and compound deficits in force regulation although the mechanism not fully understood. Increased cognitive load could disrupt descending commands to motor unit pools resulting in increased variability in muscle activation and force steadiness. This presentation highlights our recent work demonstrating that (1) impairments in force regulation worsens when accompanied by a cognitive challenge and is further exacerbated with aging; and (2) the age-related deficits in steadiness are accompanied by greater oscillations in estimated common synaptic input to motor units. These age-related impairments in steadiness are likely to be exacerbated in older clinical populations such as stroke survivors who are already challenged in single motor task force steadiness.

These findings have important rehabilitation implications and provide opportunities for high impact studies to understand motor impairments in patient populations who are typically older.

S1.3 Does regional recruitment and differential control of motor units during postural control persist in older adults?

Joshua Cohen[1], Tanya Ivanova[1], Jayne Garland[1]
[1]*Western University*

BACKGROUND AND AIM: Ageing is associated with many changes in the neuromuscular system such as degeneration of alpha motor neurons and peripheral nerves. Previously, during a task of standing and leaning in multiple directions in young adults, we observed that the ankle plantarflexors were activated in distinct regions that modulated with leaning direction. The aim of this study was to compare motor unit (MU) behaviour during this leaning task between young and older adults. METHODS: Thirty-two participants (18 older adults (aged 77±5 years), 14 young adults (aged 25±2 years) performed a multi-directional leaning task in standing. Participants stood on a force platform and maintained their center of pressure (CoP) in 5 different leaning directions at 60% and 80% of their limit of stability. High-density surface electromyography (HDsEMG) recordings were decomposed into single MU action potentials. The average firing rate, and firing intermittency were calculated from the MU spike trains, as well as the average rectified value (ARV) of MU amplitude across columns and rows of HDsEMG grid. The barycenter, calculated as the weighted mean of the maximal ARV, was used to evaluate the spatial changes in the surface representation of single MUs across different leaning directions. A MU tracking analysis was used to identify groups of MUs as being common or unique across the target directions. RESULTS: Older adults had compromised balance performance, as evaluated by larger CoP standard deviations in the X and Y directions, 95% elliptical area, and total path lengths than the young adults ($p < 0.05$; one-way ANOVAs). In young adults, the leaning directions affected the spatial representations of the unique MUs in the medial gastrocnemius (MG) and soleus (SOL) ($p < 0.05$; Kruskal-Wallis H Test), but not in the lateral gastrocnemius (LG) or in the common units ($p > 0.05$). In the older adults, there were no significant differences in the spatial representations in both unique and common units for all plantarflexor muscles ($p > 0.05$). However, the average firing rates were significantly higher in directions requiring higher force in both age groups ($p < 0.05$). Specifically, the MG and SOL unique units had significantly higher firing rates ($p < 0.05$), and the MG, LG, and SOL common units had significantly lower firing rates ($p < 0.05$) in older compared to the young adults. In both age groups, the intermittent behaviour of the unique units changed significantly among target directions and was significantly lower in the older than in the young adults ($p < 0.05$). CONCLUSIONS: The results provide evidence that older adults may lose the ability to preferentially recruit MUs regionally (as evidenced by the lack of shift in the MU barycenter). The older adults appear to rely on modifying MU firing rate and reducing intermittency of firing to control their balance during this multi-directional standing leaning task.

S1.4 Low-intensity exercise and motor functions in older adults

Tetsuya Hirono[1]
[1]*Laboratory of Neuromuscular Biomechanics, School of Health and Sport Sciences, Chukyo University*

It is recommended generally that high-intensity resistance training is important for improvement of muscle strength even for older adults. However, the ability to exercise at low intensity is also important for activities of daily lives in older adults. We have investigated the effect of low-intensity exercise on motor function in older adults. Poor muscle force control in older adults has been reported to contribute to the limitations of activities of daily living. Especially, force fluctuation during low-intensity force exertion increased with aging. Focusing on ankle plantar flexion, force steadiness of ankle plantar flexor, which is evaluated as force variability during constant force exertion around a target level, is associated with postural sway. In young adults, force steadiness at 5% of maximum voluntary contraction (MVC) is related to postural sway in a stable condition, where they are standing on a rigid and flat platform. Force steadiness at 20% of MVC is related to postural sway in an unstable condition, where they are standing on a tiltable platform (Hirono et al. Eur J Appl Physiol. 2020). In older adults, the relationships are different from in young adults. It is reported that ankle plantar flexor force steadiness is not related to postural sway in a stable condition. However, in an unstable condition, force steadiness around 20% of MVC is related to postural sway, like young adults (Hirono et al. Gait Posture. 2021). Force control around low-intensity muscle contraction is related to postural sway is also important for older adults. Those findings suggest that it is important for older adults to control low-intensity force exertion. It is reported that weight-bearing exercise can also improve muscle function, such as muscle strength and muscle quality. Then, we investigate the effect of low-intensity home-exercise on neuromuscular properties using high-density surface electromyography in older adults. High-density surface electromyography is a method to evaluate motor units firing properties. Community dwelling older adults performed home-based weight-bearing squat training for four months. Before and after the training, muscle firing properties and motor functions were evaluated. I will discuss about low-intensity exercise in older adults in this symposium.

Symposium 2 – Effect of muscle fatigue and joint loading on motor control and performance

S2.1 Effect of footwear wedges on muscle function during running induced fatigue

Uwe Kersting[1], Ryo Morikawa[1], Natalie Mrachacz-Kersting[2]
[1]German Sport University Cologne, [2]University of Freiburg

In recent decades there has been a growing interest in injury prevention as the number of distance runners increased. A systematic review has shown that the frequency of running related injuries are most common within the lower limb, and are potentially muscle function related, such as medial tibial stress syndrome, Achilles tendinopathy and plantar fasciitis [1]. Given that most running injuries are overuse syndroms, only few studies have attempted to monitor muscle function during fatiguing running bouts including the effect of footwear. The aim of the study was to assess the effect of the midsole geometry on muscle activation during a 1-h run. Subjects (N=13) ran a total of 11 km in 3 shoe types (varus, neutral and valgus). For each lap (1 km), EMG was measured for 7 lower extremity muscles and Time of Peak Occurrence and Maximum Peak Value were observed. A 2-way Anova (Lap × Shoe type) was applied for dependant variables. Some muscles showed significant interactions. There was a significant main effect of shoe type in tibialis anterior and peroneus longus and an effect of lap on all muscles showing a gradual decrease in amplitude over time. Some individuals presented drastic alterations in EMG amplitude in certain but inter-individually different muscles. Results showed that monitoring muscle activities over longer time periods offer the potential to better understand the effects of running shoe modifications on injury potential. However, such assessments require a considerable effort in data acquisition while recent developments of mobile EMG systems and textile-based dry electrode configurations may offer a way for routine implementation of such technologies.
References Lopes, Alexandre Dias, et al. What are the main running-related musculoskeletal injuries? Sports Medicine 42.10 (2012): 891-905.

S2.2 The influence of soccer induced central and peripheral fatigue on joint positioning sense

Natalie Mrachacz-Kersting[1], Uwe Kersting[2]
[1]University of Freiburg, [2]German Sport University Cologne Am Sportpark Müngersdorf 6

Background and aim: Playing soccer or other field sports often results in muscoskeletal injuries, especially at the ankle joint. Surprisingly these injuries typically occur in the second half of a soccer match and in the absence of contact with other players. One possible reason for these is fatigue. However. Little is known about the possible changes in muscle control during fatigue. The aim of this study was to quantify the effect of a soccer-specific fatigue protocol on central and peripheral fatigue and joint position sense in the ankle joint. Methods: 22 experienced male soccer players participated in two randomized testing sessions where they were asked to perform the SAFT90 or to rest for the same duration of time. Presence of fatigue was defined as a reduction of the maximal voluntary contraction (MVC) force. Voluntary activation (VA), resting twitch (RT) and the H-reflex and V-wave measured during static and dynamic (running) tasks were used to evaluate the extent of central and/or peripheral fatigue. Finally, joint position sense (JPS) of the ankle at 15° and 30° plantar flexion was evaluated. All measurements were performed before (T0) and after (T90) the SAFT90 or resting protocol. Results: MVC decreased by ∼13% at T45 ($P = 0.003$) and ∼19% at T90 ($P = 0.001$) in the intervention session, while it remained stable in the control session. The peak force of the control twitch decreased ∼13% in the intervention session from T0 to T90, with a significant effect in effect over time ($P = 0.039$). JPS at 15° increased by ∼43% ($P = 0.032$) from T0 to T90 in the intervention session. JPS at 30° increased by ∼69% ($P = 0.006$) from T0 to T90 in the intervention session. JPS total error increased by ∼57% ($P = 0.002$) from T0 to T90 in the intervention session. No significant effect were observed for VA, static and dynamic H-reflexes and V-waves Conclusion: The present study showed that fatigue was present in the plantar flexors of the ankle after a simulated soccer match. Furthermore the fatigue was indicated to be peripheral in nature, as shown by MVC and CT decreases. The implication of central factors in the voluntary force decrement was however not present, as indicated by a stable VA. Neither were there any indications of spinal or supra spinal modulation. Interestingly the present study showed that following plantar flexor fatigue the JPS accuracy of the ankle was impaired for 15° and 30° plantar flexion.

S2.3 Using robotics to evaluate the effects of forearm muscle fatigue on upper limb sensorimotor control

Mike Holmes[1], Jacopo Zenzeri[2], Davis Forman[3], Garrick Forman[1]
[1]Brock University, [2]Istituto Italiano di Tecnologia, [3]University of Guelph

Background and Aim: Although muscle fatigue is often characterized by reductions in force production, performance impairments are not always present. The distal upper limb serves as the end effector when manipulating objects, so it is important to understand how fatigue impacts sensorimotor control. By utilizing robotics, we are able to control wrist dynamics and mechanical properties to isolate variables of interest. This presentation will highlight several studies that quantify the effects of forearm muscle fatigue on sensorimotor control, including tracking performance and proprioception. Methods: To evaluate the effects of forearm muscle fatigue on tracking performance and proprioception, participants performed tasks using a 3 degrees-of-freedom wrist manipulandum (WristBot, Genoa, Italy). With the forearm resting on a surface and hand grasping the handle of the device, participants performed various sensorimotor assessments. The robot is interfaced with a virtual reality environment and tracking performance was evaluated by participants tracking an object on the computer screen. The position of the handle was displayed and participants tracked a 3:2 Lissajous curve, sized to ±45° of wrist flexion/extension and ±25° of radial/ulnar deviation. A yellow target moved around the curve at 9°/s and participants attempted to match the target using isolated hand movements. Studies have included both maximal and submaximal, isometric, dynamic and task-specific fatigue protocols. Following practice, 5 baseline traces are performed prior to fatigue. After the fatigue protocol, participants performed 7 traces from immediate post-fatigue (0 min) to 10 minutes post-fatigue. We evaluated movement smoothness (jerk ratio), shape reproduction (figural error), and target tracking accuracy (tracking error). Proprioception was assessed using a robot aided joint position matching task that required blindfolded participants to actively recreate a previous passively imposed joint angle. Results: Across different fatigue protocols, tracking performance decreased immediately post-task termination, however, the interpretation of performance recovery was complex. Jerk ratio failed to return to baseline post-task termination, while figural error returned to baseline at approximately 4-minutes post-task termination. Tracking error had a rapid recovery after the 1-minute post-fatigue assessment. Proprioception was impaired immediately post-task termination and recovered after 1 minute. Conclusion: This work provides insight into how aspects of distal upper limb motor performance are impaired following a variety of complex muscle fatigue paradigms. Robot-aided sensorimotor assessments provide accurate and repeatable measures under controlled conditions. This presentation will summarize the results from a large number of targeted distal upper extremity fatigue and performance studies and will highlight how fatigue affects mechanical and sensorimotor properties of the wrist joint.

S2.4 Impact of neck fatigue on upper limb motor performance, sensory processing and cerebello-cortical excitability following novel motor task acquisition

Mahboobeh Zabihhosseinian[1], Paul Yielder[1], Michael Holmes[2], Bernadette Murphy[1]
[1]University of Ontario Institute of Technology, [2]Brock University

BACKGROUND AND AIM: Neck muscles have a high density of sensory receptors with central and reflex connections to the vestibular and postural motor control network. Neck inputs are received by the cerebellum and contribute to the forward internal model system, for sensorimotor prediction of movements in response to motor commands, and are important for motor learning and sensorimotor integration (SMI). Altered afferent input from the neck due to fatigue alters upper limb proprioception and sensorimotor processing, suggesting that neck fatigue may also impact SMI, and cerebellum to motor cortex (M1) pathways in response to motor learning. These experiments sought to determine the effect of cervical extensor muscle (CEM) fatigue on upper limb motor acquisition and retention; and SMI, measured via early somatosensory evoked potentials (SEPs) as well as cerebellar inhibition (CBI). METHODS: In each experiment either SEPs or transcranial magnetic stimulation (TMS) measures of CBI were collected before and after the acquisition of a novel motor tracking task (consisting of tracing sinusoidal-pattern waves with the index finger). A neck fatigue or a control condition preceded the motor acquisition phase. Task retention was measured 24 hours later for both experiments. Neck fatigue: In a prone lying position, participants held a 2 kg weight against gravity with their heads in a neutral posture until they could no longer maintain the position. The control group lay in a prone position with their neck in neutral for 5 min. SEPs Measurement: Short latency SEPs were elicited via median nerve stimulation at the wrist (1000 sweeps, stimulation rates of 2.47 and 4.98 Hz) and collected pre-and post-motor skill acquisition. CBI Measurement: A double cone TMS coil stimulated the ipsilateral cerebellar cortex 5 ms before application of contralateral test stimuli to the right first dorsal

interosseous muscle M1. Cerebellar-M1 inhibition curves were collected pre-and post-motor acquisition. RESULTS: Accuracy improved post-acquisition and retention for groups ($p < 0.001$), with controls outperforming the fatigue group ($p < 0.05$) in both experiments. The fatigue group had significantly greater increases in the N24 ($p = 0.017$) and N30 ($p = 0.007$) SEP peaks. The control group showed greater cerebellar disinhibition than the fatigue group following motor skill acquisition ($p = 0.006$), with the fatigue group showing no change in CBI. CONCLUSIONS: CEM fatigue impaired upper limb motor learning outcomes in conjunction with differential changes in SEP peak amplitudes related to SMI. Lessened cerebellar disinhibition in the CEM fatigue versus control group, coupled with diminished motor learning, suggests that CEM fatigue affects the cerebellar-M1 interaction, influencing the cerebellum's ability to adjust motor output to acquire and learn a novel motor task. Neck fatigue has profound effects on both sensory processing and motor outputs, particularly those related to the cerebellum.

S2.5 Using empirical and computational models of muscle fatigue to develop and validate repetitive work thresholds in ergonomics

Nicholas La Delfa[1], Ryan Foley[1]
[1]*Ontario Tech University*

Prolonged, repetitive upper extremity work can lead to the development of neuromuscular fatigue, which has been associated with negative outcomes including reduction in task performance and increased risk for musculoskeletal disorders. In ergonomics, we aim to control the detrimental effects of neuromuscular fatigue by designing work according to recommended thresholds that consider force, repetition and duration characteristics of a work task. Decades of psychophysical research have provided important data for the development of predictive threshold equations that recommend a maximal acceptable force or effort level for a given duty cycle (i.e. percentage of total task time spent in exertion) (ACGIH TLV, 2016). These tools are specifically effective for intermittent (i.e. on-off), isotonic contractions; but challenges emerge when estimating acceptable workloads during complex force profiles, which are becoming increasingly more representative of real-world work (e.g. large distribution centers). Computational models of muscle fatigue (e.g. Potvin & Fuglevand, PLoS Comput. Biol., 2017) provide a potential opportunity for assessing and augmenting current repetitive work thresholds. These models can be used to simulate any type of force pattern or duration of exertion, whether simple or complex, and can provide an estimation as to how the neuromuscular system may respond to various workload challenges from a motor unit recruitment perspective. However, to fully rely on these computational approaches moving forward, a series of empirical studies are needed to validate model performance in both fatigue and recovery domains, as human data related to motor unit firing rate and recruitment thresholds, during both fatigue and recovery, are lacking for contractions that resemble occupational tasks. In tandem with rigorous empirical research, computational models can be used to allow for the evaluation of any combination or sequence of isotonic or complex force exertions, which has historically been a challenge for ergonomists given the infinite nature of this work. Potential exists to use such an approach to optimize allocation and sequencing of work tasks to minimize muscle fatigue and improve performance. This presentation will discuss prior efforts by our research group to validate current repetitive work thresholds via subjective and objective assessment approaches (Abdel-Malek et al., Hum Factors, 2020), and will discuss initial modeling efforts and results (Foley & La Delfa, submitted) to characterize complex work tasks, with a future vision towards developing an assessment approach to proactively evaluate any type of complex force profile in work simulations lasting up to 8-hours, or even across an entire work week.

Symposium 3 – Motor unit population behaviour in humans: Emerging avenues and challenges

S3.1 Synergistic motor neuron pools receive common synaptic input from at least two sources during voluntary isometric contractions

Alessandro Del Vecchio[1]
[1]*Friedrich-Alexander Universität, Erlangen-Nürnberg*

BACKGROUND AND AIM: The force generated by the muscles involved in an action is produced by common synaptic inputs received by the engaged motor neurons. The purpose of our study was to identify the low-dimensional latent components, defined hereafter as neural modules, underlying the discharge rates of the motor units from knee extensor and hand muscles during isometric contractions. METHODS: A total of 16 subjects performed two experiments: one group (N=8) carried out isometric knee extensions and the second group (N=8) performed index and thumb finger contractions. HDEMG signals were acquired from the vastus lateralis, vastus medialis, first dorsal interosseous, and thenar muscles. The electromyographic signals were decomposed into individual motor unit spike trains with blind source separation. The discharge times were then low pass filtered in the frequency range responsible for force production (<5Hz). We pooled the motor units from the synergistic muscles and extracted the neural modules with factor analysis and no assumptions were made regarding the orthogonality of the modules or the association between the modules and each muscle. RESULTS: Factor analysis identified two independent neural modules that captured most of the covariance in the discharge rates of the motor units in the synergistic muscles. Many motor units were strongly correlated by the module associated with the homonymous muscle, some with the synergistic muscle neural module, and some with both modules. The distribution of motor units into neural modules differed for the thigh and hand muscles; 80% of the motor units in first dorsal interosseous were more strongly correlated with the neural module for that muscle, whereas the proportion was 70%, 60%, and 45% for the thenar, vastus medialis, and vastus lateralis muscles. All other motor units either belonged to the shared modules or to the latent component for the other muscle (15% for vastus lateralis). With a simulation of 480 integrate-and-fire neurons receiving independent and common inputs, we demonstrate that factor analysis identifies these three neural modules with high levels of accuracy. CONCLUSIONS: We found that there are at least two common inputs to an individual motor nucleus. Moreover, the discharge rate of some motor neurons from an individual motor nucleus can be fully retrieved by measuring the discharge rate of the synergistic motor neurons. Our results indicate that muscle synergies arise from at least two sources of common synaptic inputs that are not distributed homogeneously among the motor units that innervate synergistic muscles.

S3.2 Non-invasive estimate of muscle fibre cross-sectional area

Andrea Casolo[1], Andrea Casolo[1]
[1]*University of Padua*

BACKGROUND AND AIM: Since the seminal work by Charriere and Duchenne (1), the gold standard technique for the evaluation of muscle fiber cross-sectional area (CSA) and typology is muscle biopsy. However, although safe and effective, it is undoubtedly characterized by a certain level of invasiveness. Because of the relation between muscle fiber diameter and conduction velocity, motor unit conduction velocity (MUCV) may be adopted as an alternative and non-invasive methodology to assess muscle fiber properties in humans. This relation has been previously assessed in animal models (2), in human patients with intramuscular EMG (3), and in healthy individuals during electrically-stimulated contractions (4). Here, we systematically explored the relation between MUCV assessed for representative samples of motor units (MU) and fiber CSA and we propose a new methodology to estimate both diameters and distribution of fibers from an EMG-derived parameter. METHODS: Twenty-nine healthy volunteers (age: 21.9±3.2yr; body mass: 82.1±13.9kg) performed linearly increasing isometric elbow flexions at forces up to 70% of the maximum, whilst high-density surface electromyography (HDsEMG) was recorded from the biceps brachii (BB) muscle and decomposed into individual MU discharge timings. MU properties (recruitment thresholds, MU RT; discharge rate, MU DR) and MUCV (MUCVAVERAGE, MUCVMIN and MUCVMAX) were estimated. Muscle fiber CSA and distribution of BB were evaluated through muscle biopsies. RESULTS: 701 unique MUs and 5617 single fibers from BB were analyzed. Positive linear associations between MUCV and MU RT were observed for all participants (R^2=0.78±0.09, P<0.001). Linear associations were observed between MUCVAVERAGE and muscle fiber type I (R^2=0.34, P=0.001) and type II CSA (R^2=0.27, P=0.003). Similarly, MUCVMAX was associated with muscle fiber type I (R^2 = 0.40, P=0.001) and to a larger extent to type II CSA (R^2=0.57, P=0.001). MUCVMIN was associated with muscle fiber type I CSA (R^2=0.23, P=0.008) only. In order to study the relation between MUCV and fiber diameters, individual MUCV data were converted into diameters (i.e. estimated) with an equation based on previously published literature data (5). Similarly, fiber CSA data were converted into diameters (i.e. measured). Linear associations were found between estimated and measured minimum (R^2=0.31, P=0.002), maximum (R^2=0.42, P=0.001) and average (R^2=0.33, P=0.001) fiber diameters. Additionally, this novel methodology allowed us to predict fiber diameters (90.8±19.6µm; 95%CI[90.2, 91.3]) from MUCV-estimated diameters (90.6±19.8µm; 95%CI[89.1, 92.0]) with a high level of accuracy. CONCLUSIONS: The results provide further evidence of the association between the distribution of MUCV and the distribution of muscle fiber CSA in healthy individuals. The proposed new methodology to estimate fiber diameters and distribution from an electromyographic parameter has the potential to open new perspectives in the study of neuromuscular adaptations to training, aging and pathology in a fully non-invasive way. REFERENCES: 1 Charriere & Duchenne, Bull Acad Med, 1865 2 Hakansson, Acta Physiol Scand, 1956 3 Blijham et al., J Appl Physiol, 1985 4 Methenitis et al., Med Sci Sports Exerc, 2016 5 Nandekar & Stålberg, Med Biol Eng Comput, 1983

S3.3 Changes in the activity of spinal motor neurons following anterior cruciate ligament reconstruction.

Stefano Nuccio[1]
[1]*University of Rome "Foro Italico"*

BACKGROUND AND AIM: Deficits in knee extension strength are common following anterior cruciate ligament reconstruction (ACLR) and are related to increased risk of re-injury. The inability to fully activate the quadriceps results from a combination of neural alterations affecting cortical, spinal and afferent mechanisms which, collectively, determine a decrease in the net excitatory drive to spinal motor neurons. We investigated the underlying adaptations occurring in the activity of spinal motor neurons by examining the discharge patterns of large populations of motor units (MUs) in the vastus lateralis (VL) and vastus medialis (VM) following ACLR. METHODS: Ten individuals with ACLR and nine controls performed a series of unilateral isometric knee extensions, consisting of submaximal force-matching tasks up to 70% of the maximal voluntary isometric force (MVIF). High-density surface electromyographic signals (HDsEMG) from the VL and VM muscles and voluntary force were concurrently recorded. A convolutive blind source separation technique was used to decompose HDsEMG signals and estimate the discharge characteristics of MU populations. A preliminary evaluation of the within-muscle coherence profiles was further conducted. RESULTS: MVIF was lower on the reconstructed side with respect to the contralateral side (818.1±131 N vs 637.8±175.4 N; P<0.05). This deficit in MVIF was accompanied by lower absolute MU recruitment (-40.1±32.9 N and -51.9±49.2 N for VL and VM, respectively; P<0.05) and derecruitment thresholds (-41.6±40.5 N and -59.5±54.3 N for VL and VM, respectively; P<0.05) and by lower MU discharge rates at both recruitment (-1.4±1.5 pps and -1.9±1.0 pps for VL and VM, respectively; P<0.05) and target force (-2.0±0.8 pps and -2.7±1.2 pps for VL and VM, respectively; P<0.05). The estimated synaptic drive to motor neurons was 27.3% lower on the reconstructed side with respect to the contralateral side (P<0.05). Deficits in MVIF were strongly and positively correlated with both deficits in MU discharge rate of the VL (R2=0.44; P<0.05) and deficits in absolute MU recruitment (R2=0.50 and R2=0.69, for VL and VM, respectively; P<0.05) and derecruitment thresholds (R2=0.60 and R2=0.68, for VL and VM, respectively; P<0.05). A strong between-side correlation was found for MU discharge rates of the VL of ACLR individuals (R2=0.90; P<0.05). The preliminary coherence analysis revealed that the relative strength of common synaptic input to motor neurons in the low-frequency range was lower for the reconstructed side with respect to the contralateral side (P<0.05). CONCLUSIONS: These results suggest that deficits in knee extension strength after ACLR may be explained by a reduced neural drive to the vasti muscles, due to changes in common inputs to alpha motor neurons. An inhibitory-facilitated reduction in motoneuronal intrinsic excitability and changes at the muscle unit level may have contributed to alterations in the activity of spinal motor neurons. These findings provide novel insights on the neural mechanisms underpinning quadriceps weakness following ACLR, which have the potential to influence rehabilitation strategies adopted in clinical settings.

S3.4 The response of a motor pool to peripheral nerve stimulation is underestimated when measured through surface electromyography.

Demetris Soteropoulos[1], Alessandro Del Vecchio[2]
[1]Newcastle University, [2]Friedrich-Alexander University Erlangen-Nürnberg

BACKGROUND AND AIM: Surface electromyography (sEMG) offers us a glimpse of the activity of spinal motoneurons (MNs) that innervate and drive a muscle and continues to be an invaluable method for assessing the state of a motor pool of MNs. One limitation of sEMG is that it represents the summed activity of the action potentials of many motor units, and given that these are biphasic potentials, this can lead to amplitude cancellation - where positive phase of one action potential cancels the negative phase of another. Although this issue has been explored previously, the degree to which amplitude cancellation might contribute to any bias in measuring the time course of inhibition and excitation of pools of motor units during stimulation is less clear. Our aim was to assess whether the response of a motor pool to a sensory stimulus, measured by sEMG, accurately represents the response of individual units from the underlying pool. METHODS: We recorded the surface activity from the Tibialis Anterior (TA) muscle using a high density grid (64 contacts), and these signals were decomposed into motor unit spike trains with a blind source separation algorithm. Participants carried out ten trapezoidal ramp contractions with a steady hold period (24 seconds long) at 20% maximal voluntary levels. To evoke responses within the TA muscle, we delivered surface stimulation of the posterior Tibial nerve at the ankle, during the hold period (DS7 stimulator, 0.5ms pulse width, intensity ~2x perceptual threshold, stimulation rate ~ 2Hz, cathode proximal). The responses of the units were measured by compiling a

peri-event spike time histogram. A sEMG signal was created by summing the spike trains of the extracted motor units, after convolving the spike train of each unit with an estimate of its derived motor unit action potential. We generated a stimulus averaged response of the rectified sEMG, normalised to the pre-stimulus levels, and measured the magnitude of any responses. RESULTS: From 6 participants we extracted 74 motor units (range 5-21). The stimulation produced both excitatory and inhibitory responses in the TA muscle and this was also seen in many of the units extracted. When we compared the magnitude of the response in the units and compared it to the magnitude of the response from the sEMG, we found that the sEMG response underestimated the response magnitude in the underlying motor pool in all subjects. In the case of the early excitatory response, its magnitude from sEMG was 7% larger than pre-stimulus levels, whereas in the motor unit data this was 19%. For inhibitory effects, the mean sEMG level was reduced by 9%, but for the motor unit pool this was 16%. The differences between the sEMG and unit data were both very significantly different ($p<0.0001$, t-test). CONCLUSIONS: Estimating the response of a motor pool to stimulation through sEMG can result in an underestimate of the response magnitude for both facilitatory and inhibitory effects.

Symposium 4 – Neural mechanisms of cross-education: Have the 100-year old clinical promises been fulfilled?

S4.1 How the Brain Becomes Activated Bilaterally during Unilateral Motor Actions: A Neural Mechanism for Therapy?

Tibor Hortobágyi[1]
[1]*University Medical Center Groningen, University of Groningen*

A peculiar phenomenon overlooked for some 100 years, now correcting textbooks, is that the activation of the brain during unilateral muscle contraction is actually not confined to structures in the contralateral hemisphere. Instead, when healthy humans contract muscles in one arm or leg, there is a concurrent activation of brain areas in the hemisphere ispilateral to the contracting muscles involved in the planning and the execution of the motor act. In addition, there is also 'associated activity' in the homologous muscle pair in the 'non-active', 'resting' limb. An understanding of the reasons and need for such muscle and brain activation is a contentious and highly relevant issue for conceptual and clinical reasons. Examining the brain ipsilateral activation using magnetic brain stimulation paradigms, EEG, MRI, and MEG would help us to better understand hemispheric specialization of willed and unwilled motor acts. We could then exploit this improved understanding of ipsilateral brain activation for developing treatment options for patients with unilateral neurological or orthopedic conditions. The purpose of this symposium presentation is to examine magnetic brain stimulation and imaging data concerning the timing, magnitude, localization, and fatigue- and task-related properties of ipsilateral activation during unilateral motor skills and contraction. The presentation will examine evidence for the functional role of this ipsilateral activation in the control of unilateral force production and in chronic adaptations to unilateral motor interventions. These data will be presented with an eye on the potential clinical utility of ipsilateral activation addressed in the subsequent three presentations in the symposium, 'Neural mechanisms of cross-education: Have the 100-year-old clinical promises been fulfilled?'.

S4.2 The positives of negatives: Eccentric exercise and cross-education effect

Ken (Kazunori) Nosaka[1]
[1]*Edith Cowan University*

Muscle contraction (or action) types affect the magnitude of the cross-education effect. There are three types of muscle contractions; isometric (static) where the force produced by a muscle (force) is equal to the load to the muscle (load), concentric (shortening) in which force > load, and eccentric (lengthening) in which force < load. Muscles can produce greater force during eccentric than isometric or concentric contractions in maximal effort, and less fatigue is induced during eccentric than other contractions. Muscle damage characterised by delayed onset muscle soreness and prolonged decreases in muscle function is induced more by unaccustomed eccentric exercise than isometric or concentric exercise. However, when the same eccentric exercise is repeated within 36 weeks, the magnitude of muscle damage is attenuated, which is known as the repeated bout effect. The repeated bout effect on the elbow flexors is also evident in the contralateral homologous muscle, although the effect is not as strong as that observed in the ipsilateral repeated bout effect, and the muscle damage protective effect does not last for 8 weeks. The contralateral repeated bout effect is also observed for the knee flexors and extensors; however, eccentric exercise of the knee extensors or flexors does not affect the elbow flexors. Many studies have shown that eccentric exercise training increases muscle strength and muscle mass greater than concentric exercise training. Several studies reported that exercise consisting of eccentric-only muscle contractions produces greater cross-education effect than exercise consisting od concentric-only or concentric-eccentric contractions. For example, when investigating the effects of eccentric-only versus concentric-eccentric contractions of the elbow flexors performed three times a week by the dominant arm during a 4-week immobilization of the non-dominant arm, decreases in muscle strength of the immobilized arm (-22%) was prevented by the concentric-eccentric contractions, and the eccentric-only contractions increased the muscle strength of the immobilized arm by 13%. A part of this appears to be associated with the greater increases in muscle strength of the trained arm after eccentric-only (21%) than concentric-eccentric contraction training (14%). The greater cross-education effect by eccentric contraction training does not necessarily mean that eccentric contractions induce greater magnitude of the cross-education effect than concentric contraction training, since some studies reported that the relative increase in the muscle strength to the trained muscle to non-trained homologous muscle was similar between the two protocols. Our recent study did not show greater effect of eccentric than concentric contractions of the elbow flexors on the contralateral brain. Nevertheless, the advantage of eccentric contractions could be used as a novel strategy for the rehabilitation of stroke patients. In the symposium, some examples how the positive aspects of the eccentric exercise in relation to the cross-education effect could be used in rehabilitation and athletic training will be discussed.

S4.3 Sparing effects of cross-education during immobilization: Candidate mechanisms and clinical potential

Jonathan Farthing[1]
[1]*University of Saskatchewan*

Over a decade ago, the first evidence emerged in the literature that effortful unilateral strength training can offset expected declines in strength and muscle size in an opposite immobilized, homologous limb. These "sparing" effects of cross-education during immobilization have since been replicated several times in the upper limbs. More recent work provides evidence that the sparing effects are muscle group specific, where unilateral strength training of the wrist flexor muscles attenuates functional losses in the opposite immobilized wrist flexors, but not the extensors. The origins of these effects are not yet well characterized, but likely involve unique and overlapping mechanisms to those elucidated for cross-education effects to a non-immobilized limb. While the novel preservation effects are often purported as clinically relevant, these studies involve short-term disuse, and do not involve injured or patient populations. Although appreciably difficult and somewhat controversial, there are now several clinical studies examining the application of cross-education strength training interventions, with just a handful of published randomized controlled trials. This symposium presentation will examine the candidate mechanisms and clinical potential of the sparing effects of cross-education during immobilization of an otherwise healthy limb and explore growing evidence from published clinical studies in the context of wrist fracture, knee surgery, and chronic stroke. These data will be presented with an eye on the potential clinical utility of ipsilateral activation addressed in the symposium, 'Neural mechanisms of cross-education: Have the 100-year-old clinical promises been fulfilled?'.

S4.4 Bilateral M1 activations of top-level Paralympic athletes with prostheses

Kimitaka Nakazawa[1]
[1]*University of Tokyo*

In this presentation, unique bilateral M1 activations of top-level Paralympic athletes with prostheses will be discussed in relation to the neural mechanisms underlying cross education. We studied functional magnetic resonance images (fMRIs) of the brain of a long jump Paralympic athlete with a unilateral below knee amputation (Para-long jumper), who won gold medals three times at the Summer Paralympic games and held the long jump world record in his category. We found that there was significant activation on both sides of the motor cortex (M1) only when the Para-long jumper was exerting voluntary contraction of his knee muscles on his amputated side. There was no such bilateral M1 activation when he exerted muscle contractions around the other lower limb joints, including the amputated ankle joint. We statistically confirmed that the observed bilateral M1 activation in the Para-long jumper was unique, as it was not observed in individuals with a below-knee amputation or unamputated long jumpers. Then we tested whether specific bilateral M1 activation would be observed in a Paralympic high-jumper with a below-knee amputation, and again observed bilateral M1 activation only when the high jumper exerted knee muscle contraction. We further performed transcranial magnetic stimulation (TMS) to test whether ipsilateral corticospinal excitability in the knee extensor rectus femoris muscle on the amputated side would be enhanced in this high jumper. The results revealed that motor evoked potentials were elicited, and the input-output relation was higher in the rectus femoris muscle on the amputated side when the ipsilateral M1 was stimulated with TMS. These results suggest that the observed bilateral M1 activation in elite Paralympic athletes is related to long-term athletic training, in other words, motor practice with an athletic prosthesis in sports activity. To further examine the relation between bilateral M1 activation and prosthesis use, we recruited thirty individuals with unilateral lower limb amputations who regularly participated in sports activities and performed the same fMRI experiments with Paralympic athletes. The results demonstrated that in twelve out of 30 participants significant bilateral M1 activation was observed, and there was a significant correlation ($p<0.05$) between years of participation in sports and the ipsilateral M1 activation level. These findings supported the idea that the bilateral M1 activation would be related to the use of prostheses with higher activity levels than daily activity use levels. Both intra- and interhemispheric neural networks are considered to underly the observed unique bilateral M1 activation in individuals with unilateral amputation. In the symposium, the supposed alteration in neural activities within motor cortex and spinal neural networks will be discussed in relation to the neural mechanisms of cross education.

Symposium 5 – Innovative approaches for the neuromechanical characterization of muscle and tendon properties

S5.1 Concurrent assessment of motor unit firing properties and fascicle length changes with high-density surface electromyography ultrasound-transparent electrodes

Eduardo Martinez-Valdes[1], Francesco Negro[2], Alberto Botter[3], Patricio Pincheira[4], Giacinto Cerone[3], Deborah Falla[1], Glen Lichtwark[4], Andrew Cresswell[4]

[1]University of Birmingham, [2]Universita` degli Studi di Brescia, [3]Politecnico di Torino, [4]University of Queensland

BACKGROUND AND AIM: Previous studies attempting to understand the relationship between muscle mechanics and neural activity have concurrently assessed changes in fascicle length and neural activation using electromyography (EMG) approaches that have low spatial sampling resolution and recorded from regions not overlying the imaged fascicles. This project aimed to assess the feasibility to simultaneously measure changes in fascicle length and motor unit (MU) firing on the same region of muscle using high-density EMG (HDEMG) electrodes that are transparent to ultrasound (US). METHODS: EMG signals and B-mode US images were recorded simultaneously from the tibialis anterior muscle of 10 participants using a silicon matrix of 32 electrodes, while performing sustained-isometric and sinusoidal-isometric contractions at two joint positions (0˚ and 30˚ plantar flexion) and torques (20% and 40% of maximum voluntary torque). In addition, anisometric concentric and eccentric ankle-dorsiflexion contractions (2 deg/s) were performed within the same range of motion assessed during the isometric contractions (0˚ to 30˚ plantar flexion) at a constant torque (25% MVC). EMG signals were decomposed into individual MUs and changes in fascicle length were assessed with a fascicle-tracking algorithm. MU firing data was converted into cumulative spike trains (CST) that were cross-correlated with both torque (CST-torque) and fascicle length signals (CST-FL). The full procedure is depicted in figure 1. RESULTS: On average, 7 (3) and 4 (1) motor units were identified on isometric and anisometric contractions, respectively. Moderate to strong cross-correlations were found for CST-FL, 0.60 (range: 0.31-0.85) and CST-torque, 0.71 (range: 0.31-0.88) across all contraction types. In addition, we identified a significant delay between CST-torque, CST-FL and FL-torque at 30° of plantar flexion and lengthening contractions ($p<0.05$). CONCLUSIONS: This study is the first to demonstrate the feasibility of recording single MU activity with HDMEG-US. The findings show a close relationship between torque, FL and CST, allowing quantifying the delay between each of these signals in a variety of conditions. Future studies, should aim to use HDEMG-US electrodes in order to better understand how changes in neural activity influence muscle mechanics and vice-versa.

S5.2 Identification of single motor units in the complex tissue dynamics of voluntary skeletal muscle contractions - using ultrafast ultrasound imaging and spatio-temporal decomposition

Christer Grönlund[1], Robin Rohlén[1], Erik Stålberg[2]

[1]Umeå University, [2]Umeå Universitet

BACKGROUND AND AIM: Force production in skeletal muscles is achieved by successive recruitment of motor units (MUs). The function of MUs is typically assessed using electromyographical (EMG) methods, and the analysis provides the basis for diagnosing neuromuscular diseases, exercise physiology and sports, and rehabilitation medicine. While the EMG records information on the neural firing pattern and the subsequent muscle fibers' electrical depolarizations, the so-called excitation-contraction mechanism links the electrical depolarization to the mechanical twitches of the fibres of an MU. Thus, recording and

analyzing the mechanical twitches may provide a complementary route to study MU function. Tissue mechanics in soft tissues can be studied using non-invasive ultrasound imaging. Recently, ultrafast ultrasound imaging, with a high frame rate (>1000 images per second), was applied to image the MUs' mechanical twitches during externally controlled electro-stimulations [1]. However, such electrical stimulation provides no information about the neural firing pattern from the spinal cord. In contrast, voluntary contractions do, but up until now, no methods have been available. In our research group we have developed methods to extract the mechanical twitches of single contracting MUs in ultrasound image sequences of voluntary contractions [2,3,4]. METHODS AND RESULTS: In this talk we will present an overview of our research on this topic. First, we present two spatiotemporal and deep learning decomposition methods to detect firing pattern and territory of single MUs in high frame rate ultrasound image sequences of voluntary contractions [2,3,4]. Methods were evaluated using simulations and results were validated using simultaneous needle electromyography. Results show that single MUs with causal EMG-twitch firings could be identified in a third of the recordings. In addition, we show results on estimation of the contractile properties of the individual MU twitches in voluntary contractions, using a previously proposed decomposition scheme of individual twitches. Results indicate that the twitch properties are associated with the inter-pulse-interval [5]. Finally, we present a method to study influence of the myofascial coupling on the ultrasound image sequence data. Domain-to-domain translation between simulated and in-vivo image sequences were used to train a model to generate authentic image sequences of the intra-muscular contraction patterns arising from the contraction of the fibres of the active MUs [6]. CONCLUSIONS: Taken together, the presented methods and results, provide tools to facilitate further advances of the new research field of neuromuscular and neuromechanical imaging. [1] Deffieux et al., IEEE UFFC, 2008, and Grönlund et al., UMB, 2013 [2] Rohlén et al., Scientific reports, 2020 [3] Rohlén et al., IEEE Access, 2020 [4] Ali et al., IEEE Access, 2020 [5] Rohlén et al., submitted [6] Ali et al, submitted

S5.3 Detecting electrical and mechanical motor unit characteristics using high density electromyography and ultrafast ultrasound

Marco Carbonaro[1], Kristen Meiburger[1], Silvia Seoni[1], Emma Hodson-Tole[2], Taian Vieira[1], Alberto Botter[1]
[1]Politecnico di Torino, [2]Manchester Metropolitan University

BACKGROUND AND AIM: Muscle contraction is associated with a cascade of electrochemical and mechanical events, from the excitation of motor units' (MU) muscle fibers to the binding of acting-myosin and thus generation of muscle force. With the development of systems of electrodes transparent to ultrasound (1), these events may be now studied collectively by combining high-density surface electromyograms (HD-EMG) and ultrasonography. To date, contributions to the field have been mainly limited to the assessment of excitation and force production at the whole muscle level. Owing to the high temporal resolution of ultrafast ultrasound (UUS) (2), in this work we propose an integrated HD-EMG - UUS method to assess the electrical and physical (i.e. mechanical and anatomical) properties of single motor units (MUs) during voluntary contractions. METHODS: The proposed method was sought to assess the spatio-temporal representation of single MU activation in ultrasound image sequences. From the firings of single MUs, obtained after decomposing HD-EMGs (3), we computed trains of MUs velocity twitches and we identified the corresponding region of muscle tissue displacement in the cross-sectional tissue velocity sequence, using spatio-temporal independent component analysis (4). The time evolution of the tissue velocity in the identified region was regarded as the MU tissue displacement velocity. The method was tested in simulated conditions and was applied to experimental signals (isometric biceps brachii contractions at 2% and 5% MVC) to study the local association between the amplitude distribution of single MU action potentials and the corresponding representation of muscle tissue displacement. RESULTS: We were able to identify the location (center) of simulated MUs in the muscle cross-section with an error (Euclidean distance) lower than 2 mm and to reconstruct the simulated MU tissue displacement velocity with a strong agreement (cc > 0.85). The analysis of 180 MUs decomposed from the experimental HD-EMGs showed a significant association between the identified location of MU displacement areas and the centroid of the transversal EMG amplitude distribution, suggesting that single MUs are represented locally in both EMGs and US images. CONCLUSIONS: Our results document the potential of the joint HD-EMG and UUS approach in probing spatio-temporal changes in muscle movement associated with the excitation of single MUs. The combination of both techniques may therefore provide a comprehensive description, at the MU level, of the electromechanical events occurring during a muscle contraction. 1. Botter et al. (2013) J. Appl. Physiol. 115(8):1203-14. 2. Souquet J & Bercoff J (2011) Ultrasound Med. Biol. 37(8), S17 3. Holobar A & Zazula D (2004) Med. Biol. Eng. Comput. 42(4), 487-495 4. Rohlén R, Stålberg E, & Grönlund C (2020) Sci. Rep. 10(1), 1-11

S5.4 Three-dimensional mapping of share wave velocity of human tendons in health and pathological states: a proof of concept

Martino Franchi[1], Tobias Götschi[2], Jess Snedeker[2], Jörg Spörri[3]
[1]University of Padova, [2]Balgrist University Hospital/ETH Zürich, [3]Balgrist University Hospital/University of Zürich

Background and aim Tendon-related complaints, such as tendinopathy, are common in athletes, workers, and the general population, with the patellar, Achilles, and supraspinatus tendons being among the most frequently affected. Degenerative processes of such conditions include changes at the biochemical level of tendon collagen fibers and maladaptations of their orientation, influencing tendon mechanical properties, as the stiffness of pathological tendons is reduced, favouring traumatic tendon injuries such as ruptures. The typical diagnostic procedure of tendinopathies includes the reporting of symptoms during daily activities, manual palpation (pressure-induced pain), and radiological detection through imaging. Ultrasound-based shear wave elastography (SWE) provides the means to quantify tissue mechanical properties in-vivo and has proven valuable in detecting degenerative processes in tendon. SWE has the potential to depict tendon damage and degeneration and predict impending structural failure. A common problem, when investigating specific tissue properties using US SWE, is that the scans are performed in a two-dimensional (2D) fashion and with a limited field of view (FOV), thus complicating the assessment of larger structures and making the retrieved results highly dependent on the portion scanned. To this end we propose a free-hand 3D ultrasound approach based on optical probe tracking on a SWE-capable US device to obtain a 3D mapping of unidirectional shear wave velocity of human tendons in vivo. Methods For the in vivo repeatability study, ten healthy subjects (mean (SD) age: 28.1 (3.0), female: 4) without history of upper or lower limb musculoskeletal pathology were included and the right patellar, Achilles and supraspinatus tendon were imaged. Further, we performed 3D SW velocity mapping of the patellar tendon in 106 youth skiers (40 female, 66 male) aged between 13-15 years. A prospective one-year survey on health problems combined with clinical assessments served to categorize symptomatic and asymptomatic skiers. Results Not only this method was validated on a synthetic phantom containing cylinders of known mechanical properties, but it also resulted technically feasible and reproducible with moderate to very good reliability and a SEM in the range of

0.300 - 0.591 m/s for patellar, Achilles and supraspinatus tendons. Skiers suffering from distal- or proximal tendon complaints showed lower mean shear wave velocity in the respective tendon region compared to asymptomatic skiers ($p = 0.035$ and $p = 0.019$, respectively). Conclusions Although further longitudinal studies are warranted to test the prospective clinical value of 3D SW velocity assessment in tendons, the current data support the usefulness of such approach in detecting potential pathological regions of tendons associated to patients' complaints. (The present talk will also present pilot data on 3D SW velocity applied to muscle tissue in vivo).

S5.5 Investigating the influence of age and sex on the activation-dependent stiffness of the pectoralis major using ultrasound shear-wave elastography

Tea Lulic[1], Cheryl Setlock[2], Joshua Leonardis[2], Madison Kulik[2], David Lipps[2]
[1]Universita degli Studi di Brescia, [2]University of Michigan

BACKGROUND AND AIM: The pectoralis major fiber regions contribute uniquely to the mobility and the stability of the shoulder complex. It is unknown how age and sex influence the activation-dependent stiffness of these regions, but this knowledge is critical to inform clinical and exercise interventions targeting the pectoralis major. The aim of the present work was to determine if activation-dependent stiffness of the pectoralis major fiber regions differs between the sexes and if it is altered with age. METHODS: Shear wave velocity (SWV) from the clavicular and sternocostal fiber regions was acquired using ultrasound shear-wave elastography in 24 healthy younger (12 males, 12 females, mean age: 25 ± 4.1 years) and 24 older (12 males, 12 females, mean age: 55 ± 3.6 years) adults. Participants performed vertical adduction and horizontal flexion torques in neutral and 90° externally rotated shoulder positions, and one of the two shoulder abduction positions (60° and 90°; Fig. 1) at varying torque magnitudes (passive, 15% and 30% of maximal voluntary contraction). Separate linear-mixed effects models for each fiber region and shoulder position were used to examine the influence of sex and age on the activation-dependent stiffness. RESULTS: Collectively, younger, and older females had greater activation-dependent stiffness in both pectoralis major fiber regions than younger and older males across all shoulder positions (all $p < 0.001$; Fig. 1). Alterations in activation-dependent stiffness due to age were more pronounced in females. Specifically, SWV in the clavicular region was reduced in older than younger females when the arm was externally rotated, and horizontal flexion torques were performed ($p < 0.001$; Fig. 1). Lastly, in the sternocostal region, older females had greater SWV than younger females when the arm was in neutral at 60° and vertical adduction torques were performed ($p = 0.0058$; Fig. 1). CONCLUSIONS: Sex and age are important factors to consider when assessing the pectoralis major fiber region activation-dependent stiffness and should be integrated when designing exercise and clinical interventions targeting the pectoralis major fiber regions.

Symposium 6 – Effect of altered sensory and cognitive processing on sensorimotor integration

S6.1 Impact of chronic pain on the detection and behavioral response to sensorimotor conflicts

Catherine Mercier[1]
[1]Université Laval - Cirris

BACKGROUND AND AIM: Pain can impact on the way we perceive our body as well as on our motor behavior. Indeed, an extensive literature shows that in individual with chronic pain, various distortions in body perception occur, such as changes in the perception of size, shape and temperature of the painful limb as well as in the perception of limb position and limb movement. Alterations can even be reported in the feeling of body ownership and of movement agency (i.e., the feeling of controlling one's actions). The aim of the set of studies that will be presented in this talk was to understand how chronic pain impact on the ability to detect sensorimotor conflicts and on the perceptual and motor response to such conflicts. METHODS: Our team has developed several protocols to generate well-controlled visuomotor conflicts using either motion capture or a robotic system combined with virtual reality. In a first series of studies, we developed a "virtual mirror" application in which an avatar responding to body movements in real-time can be used to exaggerate or reduce in a subtle manner the visual feedback on actual voluntary movements at a specific joint. In a parallel set of studies, we created more intense sensorimotor conflict situations (for example by providing feedback with a 90° rotation relative to actual movement) while measuring both the subjective somatosensory perturbations and the objective motor perturbations evoked by this sensorimotor conflict. RESULTS: When people with chronic pain are exposed to subtle conflicts, we have shown altered perception of body movement in different patient populations. Individuals with chronic low back pain exhibit a biased perception (i.e., tendency to overestimate their own movement) while those with CRPS or fibromyalgia show impaired detection of the manipulation / increased uncertainty. When people with chronic pain are exposed to more drastic sensorimotor conflict situations, we observed an increased sensitivity to conflicts that is expressed through specific evoked sensory disturbances. Moreover, we found that these sensory disturbances are more pronounced when the conflict is triggered by active than by passive movements, suggesting that it does not depend solely on the integration between two sensory modalities (i.e., vision vs. proprioception) but also depend on integration between afferent and efferent information. CONCLUSIONS: Altogether, results of these studies suggest that: 1- somatosensory information becomes less reliable in the presence of pain; 2- that visual information can influence body perception to a greater extent in individuals with chronic pain compared to pain-free controls; 3- that efferent information might play a greater role in the presence of pain. We are currently assessing underlying neurophysiological mechanisms.

S6.2 Understanding the influence of cognitive factors in pain-related corticomotor modulations: what role for kinesiophobia and pain catastrophizing?

Guillaume Léonard[1], Arnaud Duport[1], René Pelletier[2], Marylie Martel[3]
[1]Centre de recherche sur le vieillissement - Université de Sherbrooke, [2]CBI-Concordia Physiosport, [3]Univeristé de Sherbrooke

BACKGROUND AND AIM: Several studies have shown that nociception, a category of somatosensory feedback, can modulate corticomotor excitability. However, the variability of observed responses remains large and unexplained, and may depend on many factors. The aim of this study was to unveil potential sources of variation by looking at the effect of cognitive factors (kinesiophobia and pain catastrophizing) on pain-induced corticomotor modulation. METHODS: Experimental pain was induced with a 1% capsaicin cream (approx. 0.06 ml) applied on a 4 x 4 cm area on the middle volar aspect of the non-dominant forearm. Corticomotor excitability was assessed by the slopes of recruitment curves measured from the first dorsal interosseous elicited by transcranial magnetic stimulation before and during pain induced by capsaicin application. The French-Canadian version of the Tampa Scale of Kinesiophobia (TSK-CF) was utilized to measure kinesiophobia, and the French-Canadian version of the Pain Catastrophizing Scale (PCS-CF) was used to measure catastrophic thoughts. To determine if the experimental manipulation to induce pain via the application of capsaicin cream affected corticospinal excitability, the slopes of the recruitment curves for each of the participants before and during the experimentally induced pain were compared, and bivariate correlations were used to determine if there was an association between cognitive factors (TSK-CF and PCS-CF) and pain-induced changes in the slopes of the recruitment curves. Between-group analyses were also performed to examine potential differences between participants with the lowest TSK-CF and PCS-CF scores and those with the highest TSK-CF and PCS-CF scores. RESULTS: There was a moderate and positive correlation between individual changes in slope of the recruitment curves and TSK-CF questionnaire scores ($r = 0.47$; $p = 0.02$), indicating that participants with the lowest kinesiophobia scores were those who demonstrated the greatest decreases in the slope of the recruitment curve. No significant correlation was observed between the change of the slope of the recruitment curves and the PCS-CF questionnaire scores ($p = 0.20$). As for the between-group comparison, the results showed a difference between the group with lowest TSK-CF scores and the group with highest TSK-CF scores for relative differences in the slopes of recruitment curves ($p = 0.01$). There were no significant differences between the group with lowest PCS-CF scores and the group with highest PCF-CF scores for relative differences in the slopes of recruitment curves. CONCLUSIONS: Higher kinesiophobia scores during experimental induced pain were associated with smaller decreases in the slopes of recruitment curves. Kinesiophobia is a predictor of worsening clinical picture and chronic pain. It is conceivable that the decreased corticomotor inhibition in the presence of pain may contribute to the motor control changes associated that have been hypothesized to contribute to chronic pain and disability. Further study of the extrapolation of this phenomenon to individuals with chronic pain appears warranted.

S6.3 Commissural Interneurons and their role in humans

Natalie Mrachacz-Kersting[1]
[1]*University of Freiburg*

In a series of studies, we have demonstrated that sensory information arising from muscle receptors contributes significantly to the activation level of muscles located in the opposite limb. The latency of effects is too short to traverse to higher centers located within the brain, suggesting a direct connection between opposing limbs at the spinal level. Indeed our evidence suggests that, as in animals, commissural interneurons exist in humans and mediate these effects. These short-latency crossed responses (SLCRs) are significantly affected by several factors such as the shape of the input to the system, the state of the system (the reflex response may in this case even be reversed), by a central nervous system lesion where the patients are unable to present a normal walking symmetry. Further, these responses have a significant functional consequence as they alter the center of pressure (CoP) and pressure distribution under the contralateral foot and are significantly affected by fatigue. In this talk I will discuss these recent findings and present outlooks for future experiments to further enhance our understanding of interlimb communication.

S6.4 Neck Fatigue and Neck pain affect upper limb motor learning with corresponding changes in early somatosensory evoked potentials and cerebellar disinhibition

Bernadette Murphy[1], Mahboobeh Zabihhosseinian[1], Julianne Baarbé[1], Danielle Andrew[1], Paul Yielder[1]
[1]*Ontario Tech University*

BACKGROUND AND AIM: Sensorimotor integration (SMI), including proprioception and motor control, is disturbed by altered sensory input from the neck. Effective SMI is essential when learning new motor skills, and the cerebellum normally "disinhibits" to allow acquisition of novel motor skills. The neck is linked biomechanically and neurologically to the upper limbs and yet, research is limited on its role in upper limb SMI. This talk will discuss neck fatigue as an acute model, and subclinical neck pain (SCNP) as a chronic model, of altered neck sensory input and the effects on motor learning. Somatosensory evoked potentials (SEPs) measured changes in SMI and transcranial magnetic stimulation (TMS) measured differences in cerebellar inhibition (CBI). METHODS: Healthy and SCNP males and females aged 18 to 30 participated. SCNP participants with mild to moderate neck pain, which had not been treated in the past 3 months were compared to healthy controls. Neck Fatigue participants lay in a prone position with a 2kg weight suspended from their head until they could no longer hold their head in neutral. Control participants lay with prone with their head fully supported. Motor Learning: a tracking pad measured performance accuracy of pursuit of sinusoidal waveforms of varying frequency and amplitude, and retention was measured 24 hours later. SEPs: Changes in short latency SEP peak amplitudes (mean of 1000 stimuli, at 2 stimulation rates-2.47 and 4.98 Hz) were compared pre and post motor acquisition. CBI: CBI was elicited by delivering a TMS conditioning stimulus via a double-cone centred over the ipsilateral cerebellar hemisphere, 5 msec before a figure of 8 coil delivered the test stimulus over the contralateral motor cortex (M1). The conditioning stimulator intensity (CSI) that led to a 50% decrease in motor evoked potential (MEP) amplitude from the first dorsal interosseous muscle (CBI) as well as CBI +5% and 10% of CSI were measured (10 CBI MEPs averaged at each intensity and one single pulse test MEP). CBI curves were compared pre and post motor acquisition. RESULTS: SCNP vs Healthy Controls: SEPs: Both the N18 (linked to cerebellar input pathways) and N24 (reflecting activity in the inhibitory pathway between the cerebellum and primary sensory cortex) peaks differed in SCNP, and there was worse motor learning with significant correlations SEP peak alterations CBI: Healthy individuals showed the expected level of cerebellar disinhibition following motor learning, but those with SCNP did not disinhibit at all. Neck Fatigue vs Controls:: Differential effects of neck fatigue on SEP peaks related to SMI (N24 and N30) corresponded to worse motor learning in the neck fatigue group. Neck fatigue also affected CBI, resulting in less cerebellar disinhibition, and worse motor performance at acquisition and retention. CONCLUSIONS: Acute and chronic changes in neck sensory input affect upper limb motor learning, SMI and cerebellar disinhibition, which is needed to acquire a novel motor skill.

S6.5 The effect of spinal dysfunction on limb proprioception and cortical drive to muscles

Heidi Haavik[1]
[1]*Haavik Research*

There is a growing body of evidence that demonstrates vertebral column dysfunction plays a vital role in neuromuscular control, not only of the spinal column itself but also affecting limb proprioception and motor control. In a recent invited review, our team summarised the evidence about how vertebral column dysfunction, known as a central segmental motor control (CSMC) problem, alters neuromuscular function of core muscles as well as limb muscles.[1] This invited review also covered how spinal adjustments (high-velocity, low-amplitude or HVLA thrusts directed at a CSMC problem) alters neuromuscular function.[1] The literature suggests physical injury, pain, inflammation, and acute or chronic physiological or psychological stress can alter the vertebral column's central neural motor control, leading to a CSMC problem. Thus, a CSMC problem is thought to originate from an alteration in afferent input to the CNS from the paravertebral tissues (for any of the above-mentioned reasons), which leads to altered multisensory integration changing vertebral column motor control. Over time, following an injury and/or traumatic experiences and/or local inflammation the small deep paraspinal muscles are known to undergo maladaptive plastic changes, including atrophy, development of muscle fibrosis, extensive fatty infiltration and changes in muscle fibre types, from slow-to-fast twitch.[2-7] Thus

ongoing changes in afferent input from such paraspinal tissues would be expected, maintaining a CSMC problem. There is evidence from animal models that changes in vertebral motion segment movement is, for the most part, signalled to the CNS via deep paraspinal muscle afferents (type I and II) [8-10]. However, there is also evidence that afferent input from a CSMC problem involves group III and IV afferents signalling local inflammation from the tissues surrounding the CSMC problem [11, 12], possibly due to microtraumas occurring at that segment due to the poor central motor control of that segment. Many studies have explored differences in brain function between groups of people with a history of spinal dysfunction, such as recurring, mild, spinal ache pain or tension, with groups who have no such history of spinal dysfunction [13-19]. Even on pain-free days, those with a history of spinal dysfunction display altered limb neuromuscular control (as indicated by altered sensorimotor integration, proprioception and function) compared to those with healthy spines [13-19], further strengthening the notion that spinal dysfunction impairs cortical processing and multimodal integration over time. Many studies have shown spinal adjustments of such CSMC problems increase voluntary force, prevent fatigue, and improve limb proprioception, all of which mainly occurs due to altered supraspinal excitability and multimodal integration. [20-36] Again, this is thought to be due to the barrage of mechanoreceptive afferent input from and following the HVLA thrusts directed at the CSMC problem.
References 1. Haavik, H., et al., The contemporary model of vertebral column joint dysfunction and impact of high-velocity, low-amplitude controlled vertebral thrusts on neuromuscular function. European Journal of Applied Physiology, 2021: p. 1-46. 2. Brown, S.H., et al., ISSLS prize winner: Adaptations to the multifidus muscle in response to experimentally induced intervertebral disc degeneration. Spine (Phila Pa 1976), 2011. 36(21): p. 1728-36. 3. Hodges, P., et al., Rapid atro

Friday June 24, 2022

Symposium 7 – Decoding the human motor system: What have we learned so far?

S7.1 Decoding of motoneuron populations via invasive high-density EMG

Silvia Muceli[1], Ales Holobar[2], Dario Farina[3]
[1]Chalmers University of Technology, [2]University of Maribor, [3]Imperial College London

BACKGROUND AND AIM: In vivo decoding of the motor unit activity from intramuscular needles and wire electrodes has been in use for several decades to describe the discharge pattern of the motoneuron pool. Despite the validity of these methods, they provide limited information about few motor units, precluding population analysis. METHODS: We have developed high-density intramuscular and epimysial electrodes and decomposition algorithms based on blind source separation that enable the automatic decoding of several tens of concurrently active motor units, providing knowledge of the neural drive to and output characteristics of motoneurons. We have applied this novel technology in animal and human experiments i) to address fundamental properties of motor units such as territory and conduction velocity, ii) to investigate neural connectivity and correlation among trains of motor unit action potentials, and iii) to show changes in motor unit composition following transfers of motor axons originating from spinal motoneuron pools into normal and pathological target muscles. RESULTS: With our latest development, the spike trains of more than 60 motoneurons could be automatically extracted with high accuracy from isometric contractions at low force. Neural connectivity analysis showed that late recruited motoneurons inhibit the discharges of those recruited earlier. CONCLUSIONS: Our investigation shows that this technology is viable for investigating the neural drive to muscles with high accuracy.

S7.2 Networks of common inputs to motor neurons of the lower limb reveal neural synergies that only partly overlap with muscle innervation

Francois Hug[1], Simon Avrillon[2], Aurelie Sarcher[3], Alessandro Del Vecchio[4], Dario Farina[5]
[1]Université Côte d'Azur, [2]Shirley Ryan AbilityLab, [3]Nantes Université, [4]Friedrich-Alexander University, [5]Imperial College London

BACKGROUND AND AIM: Movements are reportedly controlled through the combination of synergies that generate specific motor outputs by imposing an activation pattern on a group of muscles. To date, the smallest unit of analysis has been the muscle through the measurement of its activation. However, the muscle is not the lowest neural level of movement control. In this human study, we identified the common synaptic inputs received by motor neurons during an isometric multi-joint task. We tested the hypothesis that each motor neuron would group with others in functional clusters, based on the common input received with other motor neurons. Furthermore, we hypothesized that an independent modulation of single motor neurons would be very rarely, if at all, observed. As secondary hypothesis, we predicted that motor neuron grouping solely based on common inputs would not necessarily correspond to the muscle innervation, but rather to functional associations. METHODS: We decoded the spiking activities of dozens of spinal motor neurons innervating six lower limb muscles (vastus lateralis, vastus medialis, biceps femoris, semitendinosus, gastrocnemius medialis and gastrocnemius lateralis) in 10 participants while they performed an isometric multi-joint task. This motor task consisted of producing a submaximal force with the right leg on an instrumented pedal, while seated on a cyclo-ergometer. We analyzed the activities of spinal motor neurons by identifying their common low-frequency components, from which networks of common synaptic inputs were derived. Of note, we did not impose any a priori muscle anatomical constraints in the identification of common inputs to motor neurons; however, we used a purely data-driven method based on graph theory to identify the groups of motor neurons based on their level of common low-frequency modulation in discharge rate. RESULTS: The vast majority of the identified motor neurons shared common inputs with other motor neuron(s). In addition, groups of motor neurons were partly decoupled from their innervated muscle, such that motor neurons innervating the same muscle did not necessarily receive common inputs. Conversely, some motor neurons from different muscles - including distant muscles - received common inputs. CONCLUSION: Our study supports the theory that movements are produced through the control of small numbers of groups of motor neurons via common inputs and that these groups do not necessarily overlap with the innervated muscles. In this view, a common input is an essential feature of the neural control at the motor neuron level. Flexible grouping of motor neurons by distribution of common inputs allows for a large dimensionality reduction with respect to the available number of motor neurons, as well as a large range of variability in motor tasks due the large number of potential groupings.

S7.3 Reverse engineering of motor unit firing patterns to identify the structure of motor commands

CJ Heckman[1]
[1]Northwestern University, Shirley Ryan AbilityLab

BACKGROUND AND AIM: The motor commands to motoneurons (MNs) comprise 3 basic input components: excitation, inhibition and neuromodulation. Though often overlooked in theories of motor control, brainstem neuromodulatory inputs releasing serotonin and norepinephrine can alter the output produced by a given level of excitation several-fold. Unfortunately the standard measure of neural output, EMG, reveals only the overall trajectory of motor output and contains little or no information

about how this trajectory emerges from the interactions of these three input components. In contrast, recent experimental and simulation studies show that motor unit firing patterns, especially as measured in populations by array methods, likely contain much more specific information about these input components. The ongoing goal of our simulation studies is to develop supercomputer-based techniques for reverse engineering (RE) firing patterns of populations of motor units (MUs) to identify the contributions of each of the 3 input components generating motor commands to MNs in humans. METHODS: A set of 20 models of MNs were developed, which realistically recreate the extensive data from studies in animal preparations on how both S and F MNs process excitatory, inhibitory and neuromodulatory inputs. These models were implemented on a supercomputer at Argonne National Labs. More than 300,000 combinations of excitation, inhibition and neuromodulation were applied to the simulated MNs and the resulting firing patterns catalogued. Our basic RE premise is that only a small subset of the 300,000 simulated MN firing patterns will accurately recreate a particular set of experimentally measured MU firing patterns. This subset would then allow identification of the "solution space" of combinations of excitation, inhibition and neuromodulation that generate the actual set of firing patterns. RESULTS: Thus far, we have focused on the question of whether the solution space of inputs for a particular set of outputs is in fact small enough to provide useful information on the underlying patterns of excitation, inhibition and neuromodulation. We focused on a slow triangular output with linearly increasing and decreasing EMG. The input solution space for this simple EMG pattern was huge, being achievable by many input combinations. In contrast, each simulated motoneuron firing pattern had a much smaller solution space, typically occupying only about 10% of the explored space in our initial analyses. Further work is required to identify the best technique for quantifying "how close" one set of motor unit firing patterns is to another. CONCLUSIONS: This reverse engineering approach appears to be a promising new analyses tool to achieve heretofore unprecedented insights into the structure of motor commands in humans.

S7.4 Lessons learned from high density EMG recordings in pathologic states

Nina Suresh[1], Zev Rymer[1]
[1]Shirley Ryan Ability Lab / Rehabilitation Institute of Chicago

BACKGROUND AND AIM: The increasing availability of advanced surface EMG(sEMG) recording systems and motor unit(MU) decomposition techniques has allowed motor control researchers to ask novel questions about the role of disrupted MU recruitment and rate modulation in mediating muscular weakness due to neurologic disorders, as well as to investigate the effects of rehabilitative interventions on control of muscle by the central nervous system(CNS). While the initial driver for muscular weakness in stroke or spinal injury lies within the CNS and is often manifested as a sharp reduction in motor outflow reflected in reduced magnitude of sEMG signals, there are also progressive changes in MU properties that can contribute to muscle weakness. Pharmacological interventions such as botulinum toxin can temporarily induce muscle weakness, while experimental interventions such as acute intermittent hypoxia can potentially reverse existing paresis. METHODS: In our research studies, HD(high-density) sEMG signals were recorded from a 16×8 channel flexible HDsEMG grid electrode with 4.5 mm electrode diameter and 8.5 mm inter-electrode distance(IED) using a 128-channel HDsEMG signal acquisition system (REFA amplifer from TMSi, Netherlands). In order to identify individual MU discharge properties, signals from the grid recordings were decomposed using the Convoldution Kernel Compensation (CKC) method. In general, the firing instances with PNR≥25 were selected for further analysis. In another set of studies, sEMG signals were recorded using a 5-pin sensor array (4 EMG channels) electrode and MU decomposition was accomplished using the dEMG system from Delsys, Inc. This decomposition algorithm incorporates the Precision Decomposition(PD) technique in conjunction with the IPUS(Integrated Processing and Understanding) concept from the artificial intelligence field. Joint forces were recorded with a six-degrees-of-freedom load cell. In general, EMG and force signals were collected during a sustained isometric non-fatiguing contraction using a trapezoidal force trajectory. Seated participants were provided with two dimensional visual force feedback. Amplitude characteristics of individual MU action potentials(MUAPs) were obtained using spike triggered averaging of the recorded EMG signals. Quantitative analyses of the relationships between MU discharge rates, MU recruitment thresholds, MUAP amplitude and joint force were then conducted. RESULTS: We will review briefly findings about the contributory role of MU discharge properties to muscle weakness in chronic stroke, the effects of anti-spasticity agents such as botulinum toxin on changes in muscle control and ways in which populations of motor neurons are modified by potential therapeutic interventions such as acute intermittent hypoxia. CONCLUSION: Population studies of MUs in stroke and spinal cord that allow the assessment not only of discharge properties but also of morphological changes in MUs have provided a unique opportunity to assess chronic as well as longitudinal changes in MU properties. These studies provide insight regarding the underlying neural mechanisms associated with pathological changes in motor control.

S7.5 Motor unit firing identification in electrically elicited H reflexes of Soleus muscle

Ales Holobar[1], Matjaz Divjak[1], Filip Urh[1], Matej Kramberger[1], Matjaz Vogrin[2], Milos Kalc[2]
[1]University of Maribor, Faculty of Electrical Engineering and Computer Science, [2]University of Maribor, Faculty of Medicine

BACKGROUND AND AIM: H reflex analysis has been used in the studies of neural conductivity and facilitatory and inhibitory somatosensory responses. However, the studies of individual motor units (MUs) have been lacking or have been limited to intramuscular electromyograms (EMG) that typically detect the firing patterns of a few simultaneously active MUs only [2]. We developed and tested the methodology that supports identification of MUs firings in H reflexes recorded by high-density EMG (HDEMG). METHODS: HDEMG signals were recorded by a grid of 5×13 electrodes (GR08MM1305, OT Bioelettronica, Italy) from Soleus muscle of 12 young males (age 33.6 ± 5.8 years). Participants sat in an ankle dynamometer (Wise Technologies, Slovenia) and performed from 15 s to 20 s long isometric voluntary plantar flexions at 10%, 20%, 30%, 40%, 50% and 70% of maximum voluntary contraction (MVC). Afterwards, 60 or more H reflexes were elicited by delivering single rectangular electrical impulses (1 ms) to the tibial nerve (TMG - S1 electrical stimulator, Slovenia) at three levels of background muscle activity: rest and plantar flexion at 10% and 20% of MVC. HDEMG signals from voluntary contractions were decomposed by Convolution Kernel Compensation [1] and MU filters of individual MU have been identified. Afterwards, the MU filters have been applied to HDEMG recordings of H reflexes, identifying the individual MU firings in H reflexes. MU firing latencies and peak-to-peak (P2P) H reflex amplitudes were analysed. RESULTS: 42.6 ± 11.2 MUs per participant have been identified from voluntary contractions. P2P amplitude of H reflex was 1.8 ± 2.5, 2.0 ± 2.8 and 2.4 ± 2.8 mV in relaxed muscle, and during 10% and 20% MVC contraction, respectively. When applied to H reflex recordings, the MU filters identified 14.1 ± 12.1, 18.2 ± 12.1 and 20.8 ± 8.7 firings per H reflex (Figure 1), with individual MU latencies of 35.9 ± 3.3, 35.1 ± 3.0 and 34.6 ± 3.3 ms. Standard deviation of individual MU latencies calculated across H reflexes was 1.0 ± 0.8, 1.3 ± 1.1 and 1.5 ± 1.2 ms, in agreement with results in [2]. CONCLUSIONS: We successfully identified MU firings during electrically elicited H reflexes in Soleus muscle of 12 healthy young individuals, demonstrating novel methodology for analysis of H reflexes. ACKNOWLEDGEMENT: This study was supported by the Slovenian Research Agency (project J2-1731 and Programme funding P2-0041). [1] Holobar A, Zazula D (2007). Multichannel Blind Source Separation Using Convolution Kernel Compensation. IEEE Transactions on Signal Processing, 55(9), 4487-96. [2] Burke D, Gandevia S C, McKeon B (1984). Monosynaptic and oligosynaptic contributions to human ankle jerk and H-reflex. Journal of Neurophysiology, 52(3), 435-48.

Symposium 9 – New solutions for taking care of major limb amputees: Technological developments and use of natural phantom sensations

S9.1 Assessment of motor control over the phantom limb and its relationship with phantom limb pain after hand amputation

Catherine Mercier[1]
[1]Université Laval - Cirris

BACKGROUND AND AIM: In most of the cases, limb amputation is followed by the vivid sensation that the missing body part is still there, a phenomenon called phantom limb. It is accompanied by phantom limb pain (PLP) in about half of people living with an amputation. One particularly intriguing phenomenon is that most people perceive being able to perform voluntary movements with their phantom limb. This ability is variable however as most people are generally able to move their phantom easily soon after the amputation, but in many cases this ability diminishes over time. The aim of our work was to develop methodological approaches to objectively characterize the motor capacities of the phantom limb and to assess their relationship with the severity of PLP. METHODS: First, we assessed whether transcranial magnetic stimulation (TMS) applied over the motor cortex can elicit phantom movements (different stimulation sites and intensities being randomly used) in people with an upper limb amputation. Second, we recorded electromyographic (EMG) activity from the stump muscles of people with above-elbow amputation while they made cyclic voluntary movements of their phantom and intact limbs simultaneously. RESULTS: The TMS study showed that stimulation of the area of the motor cortex previously devoted to the now-missing hand, but not stimulation of the surrounding areas, results in sensations of movement in the phantom hand. Furthermore, the magnitude of the phantom movement perceived was positively correlated with the stimulation intensity. Finally, TMS evoked sensations of movement at numerous phantom joints, including joints at which voluntary movement was impossible. Results of the EMG studies showed that in individuals with a mobile phantom limb, distinct movements of the phantom hand were associated with distinct EMG patterns in stump muscles, whereas on the intact side these muscles were not active during movements of the intact hand. On the amputated side activity in all stump muscles was cyclically modulated, and the agonist/antagonist relationships between muscles changed as a function of the movement. PLP was associated with some aspects of phantom limb motor control. First, the time needed to complete a phantom movement was systematically shorter in subjects without PLP. Second, the amount of EMG modulation recorded in a stump muscle during a phantom hand movement was positively correlated with the intensity of PLP. CONCLUSIONS: The EMG results support the existence of a relationship between the ability to move the phantom limb and PLP, although the causal relationship between these two phenomena remain unclear. Interestingly, TMS results suggest that inability to voluntarily move the phantom is not equivalent to a loss of the corresponding cortical movement representation, and therefore that voluntary access to these representations might be regained with proper training.

S9.2 Intuitive control of upper limb prostheses via phantom limb mobility

Jozina De Graaf[1], Olivier Rossel[2], Manon Chateaux[2], Amelie Touillet[3], Nathanaël Jarrassé[4], Jean Paysant[3]
[1]AMU-CNRS ISM UMR7287, [2]AMU-CNRS ISM UMR 7287, [3]Institut Régional de Réadaptation (IRR), [4]Sorbonne Université

BACKGROUND AND AIM: Phantom mobility is a frequently observed phantom sensation that is rather stable during life and that can be trained to increase the mobilization capacity. It is systematically associated with residual muscle activities that vary with the type of the executed phantom movement. We showed the last years that the surface EMG signals recorded on the residual limb can be classified according to the type of executed phantom movement and that these signals can be used to control prosthetic hand movements even in upper arm amputees. Yet, phantom mobility is slow and generates fatigue, which could impact classification metrics. The goal of this study was to explore whether daily phantom hand movement (PHM) execution can both decrease susceptibility to fatigue and improve classification results. METHODS: Phantom movement kinematics and residual muscle activities were compared between before and after a two-month home training period in 6 upper limb amputees (4 with a transhumeral and 1 with a transradial amputation, 1 scapulothoracic disarticulation). Surface EMG signals were classified to quantify a potential gain in the amount of information usable by the classifier. RESULTS: The results showed a significant improvement, whatever the level of amputation, in overall phantom mobilization ability, expressed in the number of different PHMs, speed, fluidity, reproducibility of the PHM, and the number of cycles that could be performed in a row without blocking of the movements. However, although the EMG activities also became smoother and for 5 of the 6 participants more reproducible after training, EMG classification metrics did not improve significantly. Interestingly, when new movements that emerged during the training period were included in the classifier, the rate of correct classification did not decrease, indicating that the muscle activation patterns associated with these movements were sufficiently different not to interfere with the already existing movement classes. CONCLUSIONS: Although training the phantom at home with only somatosensory feedback increases the overall phantom movement capacity, it does not increase the amount of information in the EMG signals that is used by the classifier. Additional feedback seems to be needed to increase the accuracy of the classification of the phantom hand movements. Yet, we still believe that training at home of phantom movements is useful to increase the performance of myoelectric prostheses with a control based on phantom mobility. First, training increased the number of different types of phantom movements without penalizing classification performance, thereby potentially allowing an increase in the number of degrees of freedom for prosthetic control. Second, endurance was enhanced by training, permitting a high level of endurance early in the rehabilitation process. Third, the EMG bursts became more fluid and often more reproducible. In real-life conditions, prosthesis users need the delay between their motor command and the action of the prosthesis to be as short as possible. The fact that the EMG has become more fluid and, for some of the participants, more repeatable, could prove to be an advantage when classification is performed in real time. For these reasons, we encourage considering phantom mobility by training phantom movements as early as possible in the rehabilitation process.

S9.3 Somatosensory feedback during walking with a prosthesis via phantom limb sensations

Lisa Bachini[1], Stéphane Liszez[2], Serge Mesure[1], Claire Mahé[1], Amélie Touillet[3], Isabelle Loiret[3], Jean Paysant[3], Jozina De Graaf[1]
[1]AMU-CNRS ISM UMR7278, [2]Lagarrigue Orthopédie, [3]Institut Régional de Réadaptation (IRR)

BACKGROUND AND AIM: Following lower limb amputation, amputees are trained to walk with a prosthesis. The loss of lower limb deprives them of essential somatosensory information, which is one of the causes of the difficulties of walking with a prosthesis. We here explored whether a solution to this lack of somatosensory feedback could come from natural sensations of the phantom limb, present in most amputees instead of from substitute technologies. Indeed, it is known that phantom sensations can be modulated by (i) global mechanical characteristics of the prosthesis socket, and (ii) locally applying a stimulus on an area of the residual limb. The purpose of this single case pilot study is to verify the feasibility of influencing phantom sensations perceived during walking via such socket modifications in a participant with transfemoral amputation. To study whether the different interface conditions also influenced gait pattern of the participant, a preliminary analysis of some spatio-temporal gait parameters was performed. METHODS: This study was conducted in 4 phases: (i) semi-structured interview regarding the participant's phantom sensations, (ii) mapping of referred sensations on the residual limb, (iii) designing of 4 prosthetic interface conditions : a rigid and a semi-rigid socket, each one with and without a focal pressure-increase on a specific area of the residual limb (as shown in the figure) that was determined by the mapping, and (iv) walking on a treadmill in each of the designed 4 interface conditions. In this last phase, the participant was questioned about the phantom sensations perceived during walking, and some gait parameters were recorded via wearable shoe sensors. RESULTS: The results show that phantom sensations during walking differed between the 4 interface conditions. Indeed, the type of socket influenced the vividness of phantom sensations, and the presence of a focal increased pressure influenced phantom sensations in the calf that that became systematically changing over the successive gait phases. Preliminary gait analysis shows that these modifications of phantom sensations were accompanied by significant changes in spatio-temporal parameters of the gait such as the heel strike angle that had the highest values for the participant's preferred condition (semi-rigid socket with focal pressure-increase in the socket), for both limbs. CONCLUSIONS: This study suggests that after a lower limb amputation it is possible to restore the perception of the limb evolving in action through referred sensations by modifying the design of the socket. Currently, the form of the socket is only considered in relation to support constraints, but this new approach may lead to rethinking the personalization of the interface in terms of its relationship with the phantom limb. Moreover, this one-case study suggests that phantom sensations could provide natural somatosensory information that could even dynamically vary with gait phases. This preliminary study encourages to continue the exploration in a larger population.

S9.4 Toward intuitive hybrid sensorimotor control of a prosthetic arm

Aymar de Rugy[1], Sébastien Mick[2], Effie Segas[1], Matthieu Guemann[3], Christophe Halgand[1], Jenny Benois-Pineau[4], Rémi Klotz[5], Daniel Cattaert[1]
[1]Univ. Bordeaux, CNRS, EPHE, INCIA, UMR 5287, [2]ETIS, UMR 8051, CY Cergy Paris Université, ENSEA, CNRS F-95000, [3]IRBA, unit PEACE, dept ENOP, [4]Univ. Bordeaux, CNRS, LABRI, UMR 5800, [5]CMPR Tour de Gassies

BACKGROUND AND AIM: Despite impressive progresses, difficulties in integrating realistic biomechanics as well as low level sensorimotor loops are such that current myoelectric controls are still far from perfect. We develop multiple ways to improve control intuitiveness, ranging from sensory substitution

to control based on residual stump motion, combined with gaze information and computer vision, and tested both on participants with valid arms or with amputations at humeral level, both in Virtual Reality (VR) and on a robotic platform (REACHY). METHODS: We developed and tested a system for intuitive sensory substitution of elbow proprioception, based on short bursts (100ms) of vibrotactile stimulation delivered in space and time according to the elbow angle of a myoelectrically controlled arm avatar. Following recent attempts at exploiting natural multi-joint coordination for intuitive control of distal (amputated) joints based on proximal (remaining stump) motion, we also propose an original approach that incorporates movement goal, available from object recognition with a Deep Neural Network augmented with gaze information from glass-worn camera and eye-tracker. This approach is based on an Artificial Neural Network (ANN), trained on a database of natural arm movements to predict distal joints from proximal (shoulder) motion and movement goal. Then, predictions from this ANN were used for human-in-the-loop control of either a virtual arm in VR, or of the robotic platform REACHY, a 3D-printed human like robotic arm used as a testbed for human-robot control strategies. RESULTS: Experiments on 23 participants, including 7 transhumeral amputees, showed that our novel vibrotactile feedback improved myoelectric elbow control as compared to a no feedback condition, and was preferred when added to vision. Experiments in VR showed that a generic ANN trained on natural arm movements from 10 subjects enabled 12 other subjects to pick-and-place bottles in various locations and orientations with movement times and smoothness similar to that with their natural arm. Next, we showed that 7 transhumeral amputees performed the same pick-and-place task similarly well with our context-aware proximo-to-distal control (i.e., ANN predicting distal, amputated joints) than with their natural arm (on their valid side). Finally, we showed on 12 other participants with valid arms and 2 transhumeral amputees that this control could be successfully applied to reach and grasp real objects with the robotic arm REACHY, despite slower movements associated with mechatronic issues. CONCLUSIONS: Although much remain to be done to bring these developments into real life prosthesis control, our results are promising both from the point of view of performances and amputees feedback. Moreover, by allowing natural commands of the prosthesis and its feedback sensations, our systems offer interesting perspectives for the treatment of phantom limb pain.

S9.5 Interest of multidisciplinary collaborations and personalization of care for improving the management of amputees

Amélie TOUILLET[1], Noël MARTINET[1], Isabelle LOIRET[1], Jean PAYSANT[1], Jozina DE GRAAF[2]
[1]IRR UGECAM NE, [2]ISM Aix Marseille

BACKGROUND AND OBJECTIVE: After a major limb amputation, current prosthetic medical devices do not provide direct sensory information about the subject's environmental context or the position of the prosthetic limb when manipulating an object or walking. In addition, motor control of the prosthesis is not intuitive and requires learning. These limitations have a functional impact and are responsible for a high attentional load. These consequences must be taken into account both in research projects aimed at improving prosthetic medical devices and in the management of amputees. It is necessary to precisely analyze the relevant sensory information to be restored and the best way to restore it, as well as the control modalities that can be used to improve prosthetic control without increasing the attentional load. METHODS:We will present the reasons why the presence of clinicians in a research team is important to propose solutions applicable in current practice and describe how clinicians' participation in research projects can lead to changes in their clinical practice. RESULTS: Because of their work with amputees, clinicians are at the forefront of analyzing the limitations of current prosthetic solutions and the functional needs of amputees. Since the clinicians of our center have been involved in phantom limb research projects, the systematic clinical assessment of patients has evolved both in terms of patient questioning and clinical examination. Reflections are underway on the evolution of our rehabilitation protocols, in particular regarding the implementation of phantom limb training. CONCLUSIONS: Solutions based on phantom limb or residual limb movements allow to use the potential remaining after amputation and to propose personalized solutions. The development of multidisciplinary collaborations involving researchers, clinicians and prosthesis users is fundamental to propose solutions that are adapted, acceptable and rapidly transposable into clinical practice.

Symposium 10 – Implications of correlated EMG oscillations in agonist and antagonist muscles

S10.1 Anti-phase unbalanced co-contraction practice and correlated EMG oscillations

Minoru Shinohara[1], Nayef Ahmar[1], Jun Ueda[1]
[1]Georgia Institute of Technology

BACKGROUND AND AIM: Motor performance can be influenced by the ability to control the co-contraction of antagonistic muscles. Low-frequency correlated oscillations in EMG amplitude across muscles are often present during voluntary steady contraction. These correlated oscillations may make the steady co-contraction control difficult but could be altered with the specific practice of co-contraction adjustments. Therefore, we developed an anti-phase unbalanced co-contraction practice, increasing the contraction level of one muscle and decreasing the level of the opposing muscle concurrently to match the unbalanced targets. The first aim of the study was to examine whether steady co-contraction performance is associated with the low-frequency correlated EMG oscillations between antagonistic muscles across healthy individuals. The second aim was to determine whether a bout of anti-phase unbalanced co-contraction practice alters the in-phase low-frequency correlated EMG oscillations between antagonistic muscles and improves steady co-contraction performance in healthy young adults. METHODS: Healthy young adults were divided into three intervention groups: Co-contraction, Contraction, and Control. Subjects were tested for unbalanced steady co-contractions with antagonistic muscles about the elbow joint before and after a single bout of intervention. The intensity of unbalanced co-contraction was 4% and 12% EMGmax in the flexor and extensor muscles, respectively, or vice versa. With the visual feedback of rectified EMG, the Co-contraction group practiced anti-phase co-contractions, alternating the intensity of unbalanced co-contraction between the flexor and extensor muscles. The contraction group practiced agonist contractions at 4% and 12% EMGmax. RESULTS: Mean squared error and variance of EMG amplitude during steady co-contraction were positively correlated with low-frequency EMG coherence < 3 Hz across subjects, which became more prevalent after the intervention. There was no specific effect of the co-contraction intervention on these variables. However, the change in the probability of in-phase coherence after the intervention was greatest in the Co-contraction group, followed by the Contraction group, and then the Control group. CONCLUSIONS: Healthy individuals with less low-frequency correlated EMG oscillations tend to perform steady co-contraction more skillfully. One bout of anti-phase unbalanced co-contraction practice may not acutely reduce the amount of low-frequency correlated oscillations but the occurrence of in-phase low-frequency oscillations between co-contracting antagonistic muscles in healthy young adults.
Supported by National Science Foundation (IIS 1317718)

S10.2 Correlated EMG oscillations during intended cocontraction

Yasuhide Yoshitake[1], Minoru Shinohara[2]
[1]Japan/Shinshu University, [2]Georgia Institute of Technology

BACKGROUND AND AIM: Skillful motor tasks in daily life and sports activity occasionally require voluntarily stiffening the involved joints by intentionally co-contracting the antagonistic muscles about the joint (i.e., intended co-contraction). Understanding the mechanisms for appropriate neural control of concurrent activation of agonist and antagonist muscles would help improve the motor performance. However, the mechanisms are not well-understood owing to methodological issues. The amount of force fluctuations would be attributable to the degree of fluctuations of motor unit (MU) discharge frequency and the strength of in-phase common oscillations in discharge frequency between MUs (so-called common neural input). Therefore, MU recordings would be needed to examine the mechanisms of steady co-contraction. The first purpose of the study was to examine the relation between the strength of common neural inputs to the antagonistic muscles and steady co-contraction performance. For this purpose, high-density surface EMG (HDSEMG) technique was employed to identify the discharge timing of large populations of MUs. Considering the difference between HDSEMG and conventional surface EMG (sEMG) in feasibility, accessibility, and potential application to wearable devices, the second purpose was to examine if sEMG can accurately represent the strength of common neural inputs to MUs. METHODS: HDSEMG with 64 channels and conventional sEMG with bipolar configuration were recorded from the medial gastrocnemius (MG) and tibialis anterior (TA) muscles in 15 young male adults. After determining the maximal amplitude of sEMG (sEMGmax) of each muscle, the participants performed concurrent contractions of the muscles at each 10% of sEMGmax with visual guidance for ~15 s. Rectified sEMG in low frequency (< 3 Hz; rsEMG) were calculated for both muscles. To assess the steady co-contraction performance, variance of rsEMG of each muscle was calculated during co-contractions. To estimate the representative low-frequency common neural input to each muscle, the first principal component (FPC) was calculated by principal component analysis using instantaneous discharge frequency of randomly-chosen five MUs for each muscle. The strength of common neural input to the antagonistic muscles was estimated by calculating the cross-correlation function (CCF) between (MU-based) FPC of MG and TA and between rsEMG of MG and TA. For the first purpose, linear regression analysis was performed between the peak value of CCF between FPC and variance of rsEMG across participants. For the second purpose, intraclass correlation coefficients (ICC) were assessed between peak CCF of FPCs and peak CCF of rsEMGs. RESULTS: There was a moderate positive correlation between peak value of CCF and variance of rsEMG across participants ($r = 0.54$, $P < 0.05$). A good ICC (0.74) was found between peak CCF of FPCs and that of rsEMGs. CONCLUSION: The first result suggests that lesser common neural inputs to MUs in the antagonistic muscles tend to result in steadier co-contraction performance. The second result demonstrates that the strength of low-frequency common neural input to the antagonistic muscles can be reliably estimated by rectified surface EMG in low contraction intensities at least.

S10.3 Correlated EMG oscillations during walking

Julia Choi[1], Sumire Sato[1]
[1]University of Florida

BACKGROUND: Human walking involves sequential activation of muscles during different phases of the gait cycle to control limb movement in a precise manner, and to coordinate left-right alternation. The timing and amplitude of muscle activations during walking is regulated by sensory feedback. Gait modifications in more challenging walking tasks (e.g., stepping over an obstacle) also requires a high degree of corticospinal input, where EMG-EMG coherence in leg muscles has been shown to increase during precision walking. In healthy older adults, EMG-EMG coherence is reduced during walking, which may impact one's ability to adapt their walking pattern. Here we examined age-related changes in EMG-EMG coherence during two different walking tasks, namely split-belt treadmill and visuomotor locomotor adaptation. METHODS: EMG was collected from ankle plantarflexors (soleus, medial and lateral gastrocnemius), and the proximal and distal ends of the tibialis anterior (TA) muscle using surface electrodes in healthy young adults (n = 20, 18-33 yrs) and older adults (n = 19, 68-80 yrs) during treadmill walking. During split-belt treadmill adaptation, one belt moved twice as fast as the other. During visuomotor adaptation, stepping targets for the left and right legs were mapped onto a screen with different gains (i.e., one side appears to move faster than the other). Walking adaptation was characterized by changes in step length, step time and double support time symmetry. Beta-gamma band (15-45 Hz) coherence between the proximal and distal TA (pTA-dTA) and plantarflexors in each leg was quantified over the swing and stance phases, respectively. RESULTS: During split-belt treadmill adaptation, older adults showed reduced changes in step length symmetry and greater changes in double support symmetry compared to young adults, while EMG-EMG coherence was lower in older adults compared to young individuals. Across age groups, pTA-dTA coherence in the slow leg and plantarflexor coherence in the fast leg were associated with early changes in double support asymmetry during split-belt treadmill adaptation. Visuomotor adaptation alters step length symmetry in both young and older adults, but adaptation of double support symmetry was different between age groups. Across age groups, increased pTA-dTA coherence in the slow leg was associated with more adaptation in step time asymmetry during visuomotor walking adaptation. CONCLUSIONS: Lower beta-gamma coherence in both the tibialis anterior and plantarflexors in healthy older adults compared to young adults is thought to reflect reduced corticospinal drive during walking, which has an important role in regulating the timing of step cycles. During both split-belt treadmill and visuomotor walking adaptation, reduced corticospinal drive to the tibialis anterior muscle may specifically impact the adaptation of interlimb timing parameters.

Symposium 11 – International Motoneuron Society: Advances in motoneuron physiology for the translation to human movement

S11.1 Considerations in the estimation of human motoneuron excitability

Christopher Thompson[1], Manish Suryapalam[1], Francesco Negro[2]
[1]Temple University, [2]Università degli Studi di Brescia

BACKGROUND AND AIM: Spinal motoneurons possess active channels which serve to alter their intrinsic excitability. Remarkably, the discharge of spinal motoneurons can be assessed in humans by recording and decomposing the discharge of the group of muscle fibers that individual motoneuron innervate. From these spike times, analyses can be performed to estimate the intrinsic excitability of spinal motoneurons (e.g. delta-f). In the past decade there have been substantial improvements in our ability to decompose human motor units. However, issues remain regarding the accuracy of these approaches. METHODS: Here, we assessed the impact of motor unit decomposition errors and motor unit yield on the assessment of human motoneuron excitability. An average of 19 motor units were gathered from 10 participants during performance of linear time varying contractions. Each spike from all signals was corrected for accuracy. Using these highly accurate spike time data, we created millions of hybrid spike trains by imposing six forms of errors on these signals. RESULTS: We found that errors in specific locations of the signals cause specific changes to delta-f values. For example, removing spikes at the onset of discharge and adding spikes randomly throughout the spike train caused delta-f values to increase, whereas removing spikes at the end of the contraction or randomly throughout the

contraction caused delta-f values to decrease. Interestingly, small shifts in spike times had a negligible effect on any parameter calculated. Such data are consistent across multiple muscles. CONCLUSIONS: This work suggests that errors located at the onset and offset of motor unit discharge are critical to accurate assessments of motoneuron excitability. However, outside of these edges, the precise timing of any given spike is relatively insignificant for accurate estimates of human spinal motoneuron excitability. These results provide new insights into the impact of decomposition errors on our interpretation of these data and will guide future efforts for further automation of this cleaning. Further work will be focused on using these hybrid signals to provide an index of confidence in the original signal.

S11.2 Situations in which persistent inward currents are an impediment to motor control

Gregory Pearcey[1], James (Drew) Beauchamp[1], Obaid Khurram[1], Francesco Negro[2], CJ Heckman[1]
[1]Northwestern University, [2]Università degli Studi di Brescia

BACKGROUND AND AIM: Persistent inward currents (PICs) are crucial for initiation, gain control, and maintenance of motoneuron discharge, but a basic understanding of how PICs affect motor control in neurologically intact humans is not complete. In a series of recent studies, we explored whether PICs may be an impediment to motor control in certain circumstances. METHODS: High density surface electromyography from lower leg muscles was decomposed into constituent motor unit spike trains in healthy adults during various plantarflexion and dorsiflexion tasks. In one set of experiments, triangular ramp shaped contractions were performed to 30% of maximum while the ankle joint was in either dorsiflexion or plantarflexion. In the next set of experiments, ramp shaped contractions were superimposed atop a sustained 10% effort, such that the force profile resembled a 'sombrero hat' (i.e. sombrero contractions) at various joint angles. Finally, triangular ramp shaped contractions were performed to 30% of maximum in a neutral position with and without vibration applied to the antagonist muscle. Motor unit discharge rates were computed from the inverse of the interspike intervals and PICs were estimated using the paired motor unit analysis technique (i.e. ΔF). RESULTS: Contrary to what we predicted, estimates of PICs (i.e. ΔF) were greatest at short muscle lengths. During sombrero contractions, variability in force was greater during 10% efforts performed after a superimposed triangular effort, compared to before, and this was accompanied by prolonged discharge of higher threshold motor units during this period. When examined at short muscle lengths, prolonged discharge of high threshold motor units was more manifest compared to long muscle lengths. Lastly, antagonist muscle vibration dampened estimates of PICs (i.e. ΔF) and mitigated prolonged discharge of higher threshold motor units. CONCLUSIONS: Just like muscle cramps, PICs are increased, and prolonged motor unit discharge is more apparent at short muscle lengths, but both can be dampened by input from the antagonist muscle. Therefore, PICs may underlie muscle cramps and impediments in fine force control when preceded with higher levels of effort, both of which could be detrimental to normal motor behaviour. Without appropriate inhibition, PICs can be an impediment to motor control.

S11.3 Exploring sex-related differences in motor unit control strategies: Where do we stand?

Tea Lulic[1], J Greig Inglis[2]
[1]Università degli Studi di Brescia, [2]Brock University

BACKGROUND AND AIM: Recent evidence suggests that sex-related differences exist in motor unit (MU) control strategies (recruitment and rate coding) in human muscles. However, the lack of systematic investigations on sex-related differences poses a challenge in translating research findings to optimize health and performance in both sexes. The aim of this work was to summarize the current knowledge on

sex-related differences in MU control strategies and potential factors that may contribute to these differences. METHODS: An intensive literature search was performed using subject headings and keywords related to motor unit control strategies, behaviours, and sex-related differences. The following search terms were included: 'motor unit rate coding', 'motor unit recruitment', 'sex differences', 'sex', 'motor unit', 'force', 'isometric', 'indwelling EMG', 'indwelling electromyography', 'high-density EMG', 'high-density surface electromyography', 'high-density sEMG', 'motor unit behaviour', and 'doublets'. Databases searched were Scopus (1980 - 2021), Web of Science (1980 - 2021), Google Scholar (1980 - 2021), and PubMed (1980 - 2021). Only the primary research articles were included and screened. Primary research studies with sufficiently detailed methods were included in the data analysis. RESULTS: Seven studies examined sex-related differences in MU control strategies. Higher MU firing rates were reported in females in the vastus medialis complex (up to 75% MVC; [1]), tibialis anterior (20-40% MVC; [2]), and first dorsal interosseus (50% and 70% MVC; [3, 4]). No sex-related differences existed in tibialis anterior (60-80% MVC; [2]), first dorsal interosseus (at 10% MVC; [3]), and biceps brachii (at 15% MVC; [5]). At 100% MVC, females had lower MU firing rates in the tibialis anterior [2, 6]. Decomposition of indwelling and HD-sEMG signals led to lower MU yield in females ([7-9]). Lastly, greater MU recruitment thresholds were reported for females in vastus medialis and vastus medialis oblique [1], and first dorsal interosseus [3]. In contrast, higher MU recruitment thresholds were reported for the biceps brachii in males [5]. CONCLUSIONS: Sex-related differences in MU control strategies may be due to differences in motoneuron size, density, or number. However, based on substantial knowledge gaps, it is challenging to decipher the physiological mechanisms involved. Future research should focus on systematically investigating sex-related differences in motor unit behaviour.
REFERENCES: [1] Peng et al. (2018), J Appl Physiol, 124. [2] Inglis et al. (2020), Appl Physiol Nutr Metab, 45. [3] Parra et al. (2020), Exp Brain Res, 238. [4] Herda et al. (2019), H Mov Sci, 66. [5] Harwood et al. (2014), Acta Physiol, 211. [6] Christie et al. (2010), J Electromyogr Kinesiol, 41. [7] Del Vecchio et al. (2020), J Electromyogr Kinesiol, 53. [8] Lulic-Kuryllo et al. (2021), J Neurophysiol, 126. [9] Hug et al. (2021), J Appl Physiol, 130.

S11.4 Motor unit properties during dynamic contractions

Charles Rice[1]
[1]The University of Western Ontario

BACKGROUND AND AIM: Relative to isometric contractions, much less is known about motor unit properties during dynamic contractions in which there are substantial changes in muscle length and joint rotation. One major limitation to acquiring useful motor unit signals during dynamic contractions is an inability to maintain unit selectivity from indwelling electrodes in limb muscles during dynamic movements especially at higher forces and velocities. Although not a prime contributor to elbow extension, the anconeus shows a range of recruitment and rate coding that stratify with isometric force and movement velocity similar to other larger limb muscles. Thus it is a useful model to explore motor unit properties under various conditions and tasks. Ultrasound has confirmed during elbow joint rotation that the anconeus has length changes that are relatively similar to other larger elbow extensor muscles. The small size, unique fascicular arrangement, and relatively small number of estimated motor units (MUs) likely have facilitated selective recordings during movements. The purpose is to compare MU properties recorded from the anconeus in isometric and concentric (dynamic) contractions; and in young and old adults in which there is little current insight. METHODS: Young (~10; 20-30y)) and older (~10; 75-85y) adults participated in a series of non-fatiguing brief (2-5s) isometric (90 degree elbow joint

angle) and concentric (dynamic) elbow extension contractions while attached to commercially available dynamometers (Biodex and Cybex) that recorded extensor torque, velocity and joint position. Contractions were made a various intensities (% of maximum voluntary contraction) and concentric velocities (~90 - 400 degrees/s, depending on the resistance). To record MUs, pairs of bare-tipped, hooked insulated steel fine wires (102-µm) were inserted into the anconues using a hypodermic needle (27 gauge) that was withdrawn after insertion of the wires. Surface electrodes (0.9-cm diameter, Ag-AgCl) were placed in a bipolar configuration on the skin over the muscle belly of the long head of the triceps brachii with a 2-cm interelectrode distance. Visual and verbal feedback were provided for the participants during the various tasks. RESULTS: Elbow extensor torque was ~33% lower and velocities were ~ 10% slower in aged compared with younger adults. From repeated contractions under the various tasks each participant contributed between 2 and 6 MU samples. Mean maximum MU firing rates during isometric contractions were ~24Hz but during maximum dynamic velocity they were ~39Hz. For the older group these values were: ~17 Hz and ~30 Hz, respectively. Within each MU train inter-spike interval frequencies declined at a greater rate during the dynamic contraction in the young group than for the old. For isometric contractions rates in each group remained steady. CONCLUSIONS: These results show that dynamic concentric contractions require higher discharge rates suggesting facilitation in rates compared to isometric contractions. Aged participants had lower rates for maximum isometric contractions, but they were equally well-facilitated as young adults during dynamic contractions despite lower frequencies at the onset of contraction. initial rates. Results indicate that neural drive is task dependent and during movement in older adults it is decreased less than during isometric tasks. Supported by NSERC

S11.5 Stroke-related changes in motor unit firing behavior and motor performance

Allison Hyngstrom[1]
[1]Marquette University

BACKGROUND AND AIM: Impaired rate modulation of motor units may limit motor performance during fatiguing contractions in people with chronic stroke. This study quantified stroke-related changes in average discharge rates of motor units (individually tracked and untracked) identified from high-density electromyography recordings. METHODS: In ten people with chronic stroke (5 female), motor unit firing behavior, task duration and maximal voluntary contractions strength were measured during a sub-maximal, isometric fatiguing dorsiflexion contraction in paretic and non-paretic legs. Measures of walking function were also made. RESULTS: The paretic leg MVC was less than the non-paretic leg MVC (106 ± 54 N vs. 177±114 N, P= 0.01). Task duration was shorter in the paretic leg (297±217s) as compared to the non-paretic leg (524±262s, P=0.04). This was accompanied by a greater percent reduction in mean discharge rates in the paretic leg (-16.13±16% vs. -0.23±20%, P<0.01). Task duration of the paretic leg positively correlated with walking speed (r2=0.51). CONCLUSIONS: Paretic leg muscle fatigability is greater post stroke. It is characterized by impaired rate coding and relates to measures of motor function.

Symposium 12 – Clinical application of surface EMG in neurological and neuromuscular disorders

S12.1 Assessment of aging and neurological disorders by high-density surface electromyography

Kohei Watanabe[1], Yu-ichi Noto[2], Yuichi Nishikawa[3], Ales Holobar[4]
[1]Chukyo University, [2]Kyoto Prefectural University of Medicine, [3]Kanazawa University, [4]University of Maribor

In addition to muscular factors, assessment of neural factors contributing to motor functions in older population and neurological patients would help to determine effective countermeasures against motor dysfunctions in aging or neurological diseases. High-density surface electromyography (HDsEMG) provides valuable information of neural factors such as MU discharge and recruitment patterns non-invasively. Recently, we applied this technique to older adults and patients with type 2 diabetes, Charcot-Marie-Tooth disease, and in Parkinson's disease to assess age- and disease-related alterations in neural factors for motor functions. While it was well known that older adults have decreased MU discharge rates, we reported recruitment threshold-dependent decreases in MU discharge rates in older adults (Watanabe, Holobar et al. AGE 2016) and their adaptations to resistance training and nutritional interventions (Watanabe, Holobar et al. J Gerontol A Biol Sci Med Sci 2020, Physiol Rep 2020). Type 2 diabetes patients showed greater MU discharge variability and smaller changes in spatial distribution of neuromuscular activation within a muscle during sustained contraction (Watanabe et al. Diabetes Res Clin Pract 2012, Watanabe, Holobar et al. Muscle Nerve 2013), which can be explained by diabetic neuropathy. In Charcot-Marie-Tooth disease patients, we found a lower individual MU discharge rates, suggesting that MU discharge rates detected from HDsEMG are a potential short-term biomarker of axonal damage in these patients (Noto, Watanabe, Holobar et al. Clin Neurophysiol 2021). Patients with Parkinson's disease exhibited laterality of the MU discharge rates and an absence of a relationship between the mean MU discharge rates and MU recruitment threshold (Nishikawa, Watanabe, Holobar et al. Eur J Neurosci 2020). Although alterations in neural factors had been recognized as more difficult to quantify than muscular factors, they seem to appear earlier than muscular factors. Thus, assessments of MU discharge/recruitment pattern by HDsEMG may potentially detect a prodrome of age- and disease-related motor dysfunctions.

S12.2 Harnessing the power of high-density surface EMG in amyotrophic lateral sclerosis

James Bashford[1]
[1]*King's College London*

BACKGROUND & AIM: The hallmark of amyotrophic lateral sclerosis (ALS) is neuronal degeneration, leading to profound skeletal muscle weakness and premature death. As motor neurons traverse from healthy to sick, they become hyperexcitable, developing a propensity to fire spontaneously, which can be detected downstream on EMG as fasciculation potentials. Casting the net wide with large high-density surface EMG sensors, I will explain the core components of a novel, automated quantification tool (SPiQE), developed with the primary aim of identifying and characterising fasciculations in ALS. METHODS: From multiple surface EMG electrodes, a super-channel is created, before a noise-responsive model optimises the fasciculation detection criteria. Additionally, simultaneous ultrasound and high-density surface EMG have been applied to explore the electromechanical properties of fasciculations. Expanding the battery of tests offered by the SPiQE algorithm, we have incorporated motor unit decomposition to explore neuronal behaviour during voluntary contraction in ALS. RESULTS: We have applied the SPiQE algorithm to determine its clinical utility, showing that a fasciculation frequency above 14/min in biceps brachii is a promising diagnostic aid in ALS, while the rate of change of fasciculation frequency can forecast the aggressiveness of the disease. By tracking ALS patients over the course of one year, we provided evidence of a 'rise and fall' pattern of fasciculation firing, which is best explained by a complex interplay between neuronal hyperexcitability, axonal loss and muscle fibre reinnervation. These data indicate the viability of fasciculation parameters as biomarkers of disease in ALS. Using motor unit decomposition, we demonstrated that first-recruited (slow-twitch) motor units in the latter stages of ALS developed characteristics akin to fast-twitch motor units, possibly as a compensatory mechanism for the selective loss of this motor unit subset. We hypothesised that this process may become maladaptive, highlighting a novel therapeutic target to reduce motor unit vulnerability. By combining high-density surface EMG with ultrasound, we showed that the electromechanical latency of fasciculations is prolonged in ALS, indicating an impairment of intramuscular excitation-contraction coupling. CONCLUSIONS: Our ongoing projects at King's College London (UK) aim to develop a home-based surface EMG platform. Having designed and built a customised, portable EMG recording device with our bioengineering collaborators at Imperial College London (UK), we are in the process of validating this equipment against the gold-standard in-hospital device, while also assessing its capabilities in patients' homes. This would allow more frequent and accessible sampling of patients, which could provide the necessary breakthrough to enhance the utility of neurophysiological outcome measures in clinical drug trials.

S12.3 Utilization of real-time EMG feedback to improve muscle activation during physiotherapy in acute SCI patients

Nina Suresh[1], Guijin Li[2]
[1]Shirley Ryan Ability Lab / Rehabilitation Institute of Chicago, [2]University of Toronto

BACKGROUND AND AIM: Amongst the variety of recordable physiological signals for biofeedback in neurorehabilitation, electromyography (EMG) is the most widely used and reported variable to provide feedback from the neuromuscular system. Yet after decades of research, the efficacy of EMG biofeedback is disputable. Slings therapy is a type of physiotherapy intervention that focuses on strengthening target muscle groups in gravity elimination planes. Subsequent to spinal cord injuries (SCI), slings therapy is commonly used in an effort to increase the voluntary strength of the affected muscles. Due to the nature of SCI, it is not always clear what level of muscle activation is possible in affected muscle or muscle groups; nor is the capacity for muscle strengthening predictable, as the extent of residual innervation and the capacity to reinnervate is unknown. Our primary hypothesis is that it is possible to enhance patient engagement and targeted muscle activation with the use of visual feedback of EMG signals during inpatient physical therapy in the acute stage post-SCI. METHODS: In a pilot study, our goal was to provide EMG feedback to inpatients with (cervical) SCI at the Shirley Ryan Ability Lab (SRALab), during an experimental version of slings therapy for upper arm muscles. At each session, bluetooth capable EMG electrodes were applied to the upper arm muscles targeted for slings therapy by the patient's clinician. Half of the session was a 'normal' slings therapy session, with guidance from the research therapist. In the other half of the session, both the therapist and the participant were provided with visual feedback of real-time sEMG signals recorded from the participant's muscle(s) while the therapist guided the participant in the same movements. The order of the session type was randomized. Quantitative comparisons were computed of the activity of the targeted muscle(s) with and without feedback. A secondary objective was to assess clinician and participant identified benefits as well as drawbacks of introducing EMG signals for feedback during therapy sessions. Thus, we administered surveys to both clinicians and patients to assess whether the patients and clinicians found the EMG biofeedback useful and non-intrusive during therapy sessions. RESULTS: Our preliminary results show that participants demonstrated a statistically significant improvement of muscle activation levels with the sEMG feedback compared with conventional clinical slings therapy protocols. Overall both patients and clinicians were positive about the use of EMG feedback during the sessions. CONCLUSION: We discuss the utilization of EMG signal feedback to increase activation of targeted muscles and whether this can lead to increased muscle strength and recovery. In addition, we discuss the impediments to implementation of EMG biofeedback systems during inpatient therapy sessions.

S12.4 Is Type 1 diabetes really causing a sort of accelerated muscle aging?

Giuseppe De Vito[1], Giacomo Valli[1], Rui Wu[2], Dean Minnock[2], Alessandro Del Vecchio[3], Luana Toniolo[1], Giuseppe Sirago[1]
[1]University of Padova, [2]University College Dublin, [3]Friedrich-Alexander University Erlangen-Nürnberg

BACKGROUND AND AIM: Type 1 diabetes (T1D) can instigate changes in skeletal muscle resembling a sort of accelerated aging. In fact, the disease is often associated with decreased muscle mass and function and alterations in the composition and metabolic activity of muscle fibres, including mitochondrial disfunction. Based on these observations, it is reasonable to assume that the behaviour of the single motor units (MUs) is also altered in this condition. Therefore, we investigated these aspects by combining a direct motor units (MUs) behaviour analysis using high-density electromyography (HD-EMG) with muscle composition analysis using muscle biopsies. METHODS: Sixteen participants, eight T1D (4M/4F), without known diabetic comorbidities, and eight Non-D healthy participants (4M/4F) gave their written, informed consent to participate in the study. The HD-EMG was recorded from the vastus lateralis (VL) muscle, using a grid of 64 electrodes (5 columns × 13 rows; gold-coated; diameter of 1 mm; inter-electrode distance of 8 mm), during isometric trapezoidal contractions executed at 20 and 40% of maximum voluntary isometric contraction (MVIC) and characterized by 3 phases: a linear increase (recruitment phase) in force at 5% MVIC/s, a 20-s constant force at target (plateau phase) and a linear decrease (derecruitment phase) in force at 5% MVIC/s. Muscle biopsies were collected, in a separate day, from the VL and myosin heavy-chain (MHC) composition was determined using sodium dodecyl sulphate-polyacrylamide gel electrophoresis. RESULTS: Participants were comparable for body composition and MVIC. After the HD-EMG decomposition, a total of 288 MUs were identified. MUs recruitment thresholds did not differ between the two groups, both at 20 and 40% MVIC. MU discharge rate (DR) was reduced in participants with T1D at recruitment, derecruitment and plateau, both at 20 and 40% MVIC ($p<0.001$; for derecruitment at 40%, $p<0.05$). MU conduction velocity (CV) was reduced in T1D at 40%MVIC, both at recruitment and plateau ($p<0.001$). The same trend was observed for the amplitude of the MUs action potential (RMS of the action potential) that was reduced during the plateau phase at 40%MVIC ($p<0.05$). MHC composition did not differ between T1D and Non-D. CONCLUSIONS: The MUs analysis indicates a slowing down of the neuromuscular system in the T1D participants as demonstrated by the reduced CV and DR, particularly at 40%MVIC, which could support the notion of an accelerated aging. However, the analysis of muscle fibre composition did not corroborate this in terms of a potential shift toward a more predominant slow phenotype. Nevertheless, the analysis is not conclusive as we could not perform histochemistry to quantify the size and distribution of muscle fibres. Further investigation will be warranted to understand the cause of the "slower" neuromuscular condition in T1D.

S12.5 Changes in motor unit firing and recruitment in response to deep brain stimulation and levodopa in Parkinson's disease

Madeleine Lowery[1], Ben O'Callaghan[1], Jeremy Liegey[1], Erlick Pereira[2], Richard Walsh[3]
[1]University College Dublin, [2]St George's, University of London, [3]Tallaght University Hospital

BACKGROUND: Deep Brain Stimulation (DBS) is an established surgical treatment for the symptoms of Parkinson's Disease (PD) with demonstrated ability to control motor fluctuations. Although both DBS and levodopa-based therapies lead to suppression of Parkinsonian symptoms, their exact mechanisms of action and their influence on motor unit activation patterns are not well understood. To address this, the aim of this preliminary study was to investigate the effects of both DBS and levodopa on surface electromyography (sEMG) signal features and motor unit firing properties in individuals with PD using high-density sEMG. METHODS: Five participants (66.33 ± 6.19 years, 3 male) who had previously undergone DBS surgery for PD were recruited through the Dept. of Neurology, Tallaght University Hospital, Dublin. Abduction force and sEMG from the first dorsal interosseous muscle were recorded during a series of 30 s isometric contractions at 10 %, 20 % and 30 % of maximum voluntary contraction (MVC). sEMG was recorded with a 128-channel electrode array (BioSemi, Amsterdam, NL) with 5 mm inter-electrode distance, 1 mm electrode diameter. The experimental protocol was repeated four times in a single recording session with DBS on and DBS off, both on and off medication. sEMG data were decomposed into individual motor unit spike trains using a convolutive blind-source separation algorithm [2]. Motor unit action potential (MUAP) waveforms for each decomposed motor unit were obtained by spike-triggered averaging and matched across trials to track motor units across conditions. Linear mixed effects models were used to assess the effects of medication, stimulation and force level. RESULTS: An effect of both levodopa and DBS on sEMG and motor unit features was observed. Force coefficient of variation was significantly reduced with DBS ($p=0.004$). Medication resulted in a decrease in EMG amplitude ($p<0.001$). Motor unit mean firing rate and MUAP amplitude were also reduced with medication ($p<0.001$ for both), while motor unit recruitment threshold increased ($p=0.002$). Beta-band coherence between motor unit firing was reduced when patients were on medication ($p=0.05$). DBS increased motor unit mean firing rate and decreased discharge variability ($p=0.0008$; $p=0.002$). Motor unit recruitment threshold and synchronization were significantly lower with DBS on ($p=0.002$, $p=0.003$, respectively). CONCLUSIONS: The results provide preliminary insights into how motor control is altered by neuromodulatory and pharmacological therapies for Parkinson's disease. Alterations in motor unit recruitment and firing patterns were observed with medication and DBS. Although both treatments alleviate Parkinsonian symptoms, the results presented suggest that each have distinct effects on motor unit firing rates, firing variability and recruitment thresholds. References [1] Limousin et al., NEJM, 339(16):1105±1111, 1998. [2] Negro et al., J Neural Eng 13(2), 2016.

Saturday June 25, 2022

Symposium 13 – Is neuroplasticity functionally related to exercise intensity in health and disease?

S13.1 Do acute and chronic exercise-induced improvements in cognitive function scale with changes in neuroplasticity in healthy younger adults?

Paulo Cezar Santos[1], Tibor Hortobágyi[2]
[1]Weizmann Institute of Science, [2]Weizman Institute of Science, [2]University Medical Center Groningen, University of Groningen

The ability of the central nervous system to adapt to internal and external stimuli by altering neurons' structure and function defines neuroplasticity. Flexibility and adaptability of the nervous system ensure the daily and emergency functioning of the motor-cognitive system. Physical exercise is an effective physiological stimulus to model neuroplasticity. Indeed, a single bout of aerobic exercise can improve cognitive function and induce lasting changes in markers of neuroplasticity. Even healthy younger adults around age 20 with intact cognition can improve cognitive function and such changes are often accompanied by adjustments in markers of neuroplasticity. However, it is still unclear if changes in cognition and neuroplasticity scale with exercise intensity and the co-occurring changes are interrelated. This symposium presentation will review evidence of whether neuroplasticity scales with exercise intensity and if the exercise-induced brain changes are functionally relevant in healthy younger adults. While experimental evidence consistently suggests that both high- (HI) and low-intensity (LI) exercises vs. control (CG) induced moderate to strong functional and behavioral changes in younger adults (Cohen's d: HI=0.51; LI=1.75, and CG>0.01), in terms of neuroplasticity, such effects varied from minimal to strong effects (d range: 0.00 to 4.24) depending on the neuroplasticity marker. The inconsistent results might be related to differences in the sensitivity between neuroplasticity outcomes. Whilst exercise has a low potential to improve brain structure (e.g., brain area or volume) in healthy younger adults in the short run, neurochemical markers appear to be more responsive to the exercise stimulus, as neurochemical markers tend not to have a clear "ceiling value". It seems that the responsiveness of neuroplasticity markers to exercise varies according to the type, nature, duration, and the timing of when the marker is assayed, and these factors might in turn be related to the intensity of exercise. In summary, although both LI and HI acute and chronic exercise can induce behavioral changes, the accompanying changes in neuroplasticity can be inconsistent and uncorrelated with the behavioral changes in healthy younger adults. Still, such data provide insights into the mechanisms of how exercise interventions can improve motor-cognitive functions in older adults with and without motor-cognitive dysfunction. These data will be presented as the 1st talk in the symposium, 'Is Neuroplasticity Functionally Related to Exercise Intensity in Health and Disease?'.

S13.2 Exercise intensity and neuroplasticity in healthy older adults

Nárlon C Boa Sorte Silva[1], Guilherme Moraes Balbim[1], Teresa Liu-Ambrose[1]
[1]*The University of British Columbia*

BACKGROUND AND AIM: Despite evidence suggesting that exercise can promote neuroplasticity in healthy older adults, the role of exercise intensity is still debated. METHODS: We conducted a literature review to investigate whether exercise intensity can modulate differing levels of neuroplastic adaptations in dose-dependent manner, and whether such adaptions would result in meaningful change in cognitive and functional outcomes in this population. RESULTS: We will discuss the current evidence on the intricate relationship between exercise-induced neuroplasticity with exercise modality and intensity in otherwise healthy older adults. CONCLUSIONS: If intensity is crucial to modulate exercise-induced neuroplasticity, the results can aid in refining exercise prescription and promote more clinically meaningful outcomes in healthy older adults.

S13.3 Exercise-induced neuroplasticity in Parkinson's disease: A summary of current evidence.

Hanna Johansson[1], Erika Franzén[1]
[1]*Karolinska Institutet*

BACKGROUND AND AIM: Over 6.1 million people worldwide live with Parkinson's disease (PD), and it is now the fastest growing neurological disorder. As of today, all available therapy options are symptomatic, meaning that they are not curative, neuroprotective or disease-modifying in nature. Exercise is widely accepted as a non-pharmacological treatment, and meta-analyses have overall reported positive effects of physical exercise for people with PD. The estimated effect sizes however differ substantially over both outcomes and exercise type. Over the last decades there has also been an increasing interest in whether physical exercise has neuroprotective mechanisms in PD. The purpose of this symposium presentation is to summarize current findings of exercise-induced neuroplasticity in humans with PD, and to examine the extent to which exercise intensity matters. METHOD AND RESULTS: The handful of reviews which have set out to compile the evidence point in a positive direction, towards exercise having a possible neuroprotective effect. Emerging evidence suggests that many forms of physical exercise may lead to changes in markers of neuroplasticity both regarding brain function and brain structure, but less so along a neurochemical pathway. Unfortunately, small sample sizes, heterogenous interventions, heterogenous evaluative methods of neuroplasticity, as well as underreporting or missing information on associations between exercise stimulus-induced plasticity and clinical symptoms make attempts to synthesize evidence challenging. CONCLUSIONS: From a neurorehabilitative standpoint it is also rather uninformative when changes in neuroplasticity after a training period is presented without a behavioural change to correlate it with. In order to augment functional outcomes in the PD population we need interventions that adheres both to basic training principles (specificity, progressive overload and varied practice), as well as to key elements that harness neural activity (intensity, repetition and timing). These data will be presented as the 3rd talk in the symposium, 'Is Neuroplasticity Functionally Related to Exercise Intensity in Health and Disease?'.

S13.4 Do Dementia Brains Sustain Capacity for Exercise-Induced Neuroplasticity and Slow Disease Progression?

Tibor Hortobágyi[1], Urs Granacher[2]
[1]University Medical Center Groningen, University of Groningen, [2]University of Potsdam

As one new case of dementia is detected every seven seconds around the world, it is not surprising that the number of dementia patients may reach 152M in 2050. With no cure in sight and drug trials ending with disappointing or controversial results, non-pharmaceutical interventions are needed to address this pressing health care and societal issue. The positive correlation between human brain size and endurance-exercise capacity suggests co-evolution between locomotor activity and cognition. However, it remains unclear and controversial if human brain afflicted by mild cognitive impairment (MCI) or Alzheimer's disease (AD, the most common form of dementia) retains its capacity for exercise-induced neuroplasticity and slow or perhaps even halt progression of diagnosed MCI and dementia. The purpose of this symposium presentation is to examine if neurodegeneration affects capacity for neuroplasticity in the human brain and if physical exercise can capitalize on any neuroplasticity that survives the disease. While early exercise studies seemed promising to induce favorable changes in processing speed, executive function, memory, and disease progression, systematic reviews have in contrast recently revealed that such behavioral changes induced by physical exercise were minimal at best in individuals with MCI and dementia (effect sizes: 0.1 to 0.4). Accumulating evidence from non-invasive magnetic brain stimulation (TMS) studies in turn suggests that indirect measures of neuroplasticity such as resting motor threshold, short afferent inhibition, short-interval intracortical inhibition, and long-interval intracortical inhibition, long-term potentiation, are impaired in MCI and Alzheimer's disease (AD). Taking levodopa reversed long-term-potentiation-like plasticity induced by 1-Hz repetitive TMS in healthy adults but such reversal was absent in AD. Limited imaging evidence suggests exercise-induced neuroplasticity in MCI but neurogenesis is a less likely mechanism implied as demonstrated by meta-synthetic evidence. Taken together, the emerging hypothesis is that perhaps the efficacy of exercise as a non-pharmaceutical agent to slow cognitive impairment could be boosted by supplemental non-invasive brain stimulation, which alone seems to be also moderately efficacious to slow disease progression in

MCI and AD. These data will be presented as the 4th talk in the symposium, 'Is Neuroplasticity Functionally Related to Exercise Intensity in Health and Disease?'.

De Luca Symposium

DS1 Planting the CEDE: Advancing the use and reporting of EMG

Manuela Besomi[1]
[1]*The University of Queensland*

The quality of electromyographic (EMG) recordings and the validity of the interpretation of signals depends on many features that extend from technical considerations to the interpretation of the derived measures. Selection of the ideal experimental design is paramount yet can be difficult. The Consensus for Experimental Design in Electromyography (CEDE) project is an international initiative that aims to develop consensus-based matrices to guide decision-making in the recording, analysis, and interpretation of EMG data across multiple applications. The team comprises 21 senior researchers from 12 countries around the world from diverse backgrounds. Each matrix is led by an early/mid-career researcher and a selected group of CEDE members. I am the Research Coordinator of this project, in which I oversee and coordinate each team, conduct the consensus process and analysis, and facilitate the discussions between teams. We have published four matrices: *Electrode Selection, Amplitude Normalization, Terminology, and High-density Surface EMG* matrices, and we currently have three more under consensus.

These matrices have had a large impact to date – within ~4 years since the first publication; >200 citations, Field-Weighted Citation Impact (FWCI) between 4.53-12.73 (i.e., they have been cited >12 times the average of similar publications), they are in the top 5% most cited publications worldwide, and in the top 5% of all research outputs scored by Altmetric. The implementation of these initiatives requires further planning and involvement with the end-users. Without targeted knowledge translation strategies, it is likely that the CEDE recommendations will benefit only a small proportion of the researchers and clinicians (and patients) for whom they are intended. We are currently working on how to best disseminate and translate this novel knowledge into practice beyond publications.

DS2 Spatial lower limb myoelectric activity during human locomotion via high-density electromyography

Bryan Schlink[1]
[1]*Emory University School of Medicine*

High-density EMG is a simple, non-invasive technique to capture both the spatial and temporal properties of muscle activation. Though traditionally used in relatively stationary experimental conditions, recent technological and signal processing advances suggest high-density EMG can be expanded to more dynamic settings with high fidelity. In this talk, I will cover research from my doctoral dissertation aimed at establishing high-density EMG as an effective tool for capturing spatial myoelectric activity during human movement. First, I'll discuss how lessons learned from similar high-density electrophysiological systems were instrumental in developing signal processing techniques for selective removal of motion artifacts. Then, I'll show results from the first comprehensive analysis of spatial muscle activity in various lower limb muscles across a range of walking and running speeds. Finally, I'll demonstrate how localized muscle fatigue affects spatial neuromuscular recruitment in the medial gastrocnemius muscle during locomotion.

DS3 The brain in its body: Quantitative and non-invasive assessment of human motor control through muscle synergy theory

Marco Ghislieri[1]
[1]*Politecnico di Torino*

The organization of the Central Nervous System (CNS) in controlling and coordinating a large number of muscles during different motor tasks still represents an open issue in the field of motor control. The CNS may decrease the complexity of motor control by reducing the dimensionality of the controlled variables (i.e., the number of muscles, joints, etc.). In the last years, the muscle synergy theory was proposed for the non-invasive and quantitative assessment of the modular organization of the CNS during different movements (i.e., walking, running, cycling, balance, etc.). According to this theory, the CNS controls a small number of muscles rather than coordinating every single muscle that is involved in a specific motor task. These small groups of muscles are commonly named muscle synergies and are defined as the coherent activation, in space and time, of a group of muscles. During this talk, the effectiveness of the muscle synergy theory in modeling the complexity of motor control of healthy and pathological subjects will be presented and discussed from both a methodological and an application-oriented point of view.

Symposium 14 – Understanding the impact of upper extremity fatigue on the motor system to better detect and manage it

S14.1 Shoulder fatigue in the dominant arm impacts upper limb movement in both the dominant and non-dominant sides

Jean-Sebastien Roy[1], Frederique Dupuis[1]
[1]*Université Laval*

Background: Fatigue is a daily encountered condition that has been suggested to lead to the kinematic changes observed during arm elevation in individuals with shoulder pain. In healthy participants, we already know that fatigue leads to kinematic adaptations at the shoulder joint when performing tasks at the waist level. However, there is a need to better understand the impact of fatigue during tasks in elevated positions, since overhead activities are frequently performed during daily life. On the other hand, it has been reported that fatigue could have cross-over effects, meaning that having fatigue in one shoulder could lead to contralateral adaptations. As kinematics changes can increase mechanical load and lead to injuries, it is important to better understand how fatigue influences shoulder movements. The objectives of these projects were to investigate 1) how fatigue influences shoulder kinematics and performance during a reaching task performed in elevated arm positions, and 2) whether fatigue in the dominant arm has cross-over effects on the non-dominant arm when performing reaching task .
Methods: Two projects were realized. In both projects, 40 healthy participants were recruited and randomly assigned to either the Control Group or the Fatigue Group. Participants in both projects completed a reaching task in a virtual reality environment twice: baseline phase and post-experimental phase. Following the baseline phase, the Fatigue Group completed a shoulder fatigue protocol with their dominant arm, while the Control Group took a break. Thereafter, the reaching task was repeated. For

Objective 1, the reaching task was performed in both phases with the dominant arm, while for Objective 2, with the non-dominant arm. Upper limb kinematic and performance data were collected while reaching. Two-way repeated-measures ANOVAs were performed to determine the effects of fatigue. Results: For Objective 1, a significant ($P < 0.05$) decrease in glenohumeral elevation, and an increase in trunk flexion and rotation and sternoclavicular elevation were observed following the fatigue protocol in the Fatigue group compared to the Control Group. The Fatigue Group also had a significant decrease in movement speed. As for Objective 2, the main cross-over effects were observed in the performance as the participants with fatigue in the dominant arm had a significant decrease in movement speed and accuracy while reaching with their contralateral arm. Conclusion: These studies show the impact of fatigue on shoulder movements and performance during an upper limb reaching task in elevated arm positions. New movement patterns and altered performance were observed when performing the reaching task in a fatigued state. Furthermore, fatigue at the dominant shoulder impacted movement performance of the contralateral arm. These studies highlights the importance of considering fatigue as a potential factor influencing shoulder movements.

S14.2 Real-time wearable biomedical device based on IMU and EMG sensors to prevent musculoskeletal disorders in manual workers

Alexandre Campeau-lecours[1], Marianne Boyer[1], Jean-Sébastien Roy[1], Laurent Bouyer[1]
[1]*Université Laval*

BACKGROUND AND AIM: Work-related upper extremity musculoskeletal disorders (WRUED) are a major problem in modern societies as they affect the quality of life of workers and lead to absenteeism and productivity loss. According to studies performed in North America and Western Europe, their prevalence has increased in the last few decades. This challenge calls for improvements in prevention methods. The aim of this project is the development of a wearable sensor system to analyze worker's physical work demands and provide feedback to users and clinicians. The hypothesis is that such systems could decrease the physical work demands and ultimately prevent musculoskeletal disorders. METHODS: Using an interdisciplinary user-centered methodology, a real-time wearable device using IMU and EMG sensors was developed. Different prototype versions were developed in iteration between development and preliminary validation phases. RESULTS: The device is composed of a) a Cortex-M0 microcotroller, b) IMU and EMG sensors, c) retroaction components (visual, sound, haptic), and d) a memory card to save data. IMU: Algorithms to estimate the arm elevation and extract pertinent clinical information in real-time (ex. number of elevation and time in elevation) were implemented on the device. EMG: Algorihtms to evaluate muscle fatigue in real-time are under development and will be integrated to the device. CONCLUSION: Future work will consist in pursuing the development and performing a clinical validation of the device in terms of usability, acceptability and satisfaction.

S14.3 The effect of different fatigue location on repetitive pointing task performance: What novel information can we gain from uncontrolled manifold analyses?

Matthew Slopecki[1]
[1]*McGill University*

BACKGROUND AND AIM: Compensatory strategies in motor patterns, such as changes in motor variability, have been observed as ways to mitigate the development of fatigue from repetitive upper limb movements [1]. Studies have investigated how fatigue induced locally at individual joints may affect patterns of multijoint movements, quantifying single joint and intersegment variabilities [1].

However, whether these variability patterns help or impede the overall task performance, is unclear. We sought to quantify the effects of upper limb join fatigue on useful and harmful variability patterns of a multijoint task using the Uncontrolled Manifold (UCM) framework. METHODS: Twelve (5m/7f) participants completed a repetitive pointing task (RPT), where they repetitively moved the dominant index finger between two targets (30% and 100% of maximal reach) placed at shoulder height, at rest and after isometric, exhaustive fatigue protocols of the shoulder (SF), elbow (EF) and trunk (TF) [1]. Kinematics of the trunk and upper limb were sampled (120 Hz) using a 7-camera motion capture system. A kinematic model was created following ISB recommendations [2]. UCM framework [3] linked elemental variables (degrees of freedom at a joint) to endpoint fingertip position. Reaches were separated into phases: Early (0 - 30%), Middle (40 - 60%) and Late (70 - 100%). A mixed ANOVA determined effects (Phase, Fatigue location) on useful (VUCM) and harmful (VORT) variance components. A two-way ANOVA determined effects (Phase, Fatigue Location) on Synergy Index (ΔVZ) data. RESULTS: Significant main effects of Fatigue Location: $F (3, 516) = 5.41$ $p < 0.01$, partial $n2 = 0.03$; and Phase: $F (2, 516) = 8.23$, $p < 0.01$, partial $n2 = 0.03$, were observed on the variance data. SF caused significant increases in both variance components. For ΔVZ, significant main effects were observed for Fatigue Location $F (3, 516) = 5.30$, $p < 0.01$, partial $n2 = 0.03$; and Phase: $F (2, 516) = 8.13$, $p < 0.01$, partial $n2 = 0.03$. Following SF, a decreased ΔVZ was observed in the late phase of movement. CONCLUSIONS: The greatest reorganisation of the motor control system during the performance of the RPT occurred after fatigue was induced on the shoulder, compared to other fatigue locations. This reorganisation stabilized the performance of the RPT, through relative increases in useful and harmful variance components. This suggests an ability of the motor control system to mitigate the onset of localized fatigue. However, a relative reduction of the synergy index in the late phase of movement following shoulder fatigue suggests that the motor control system was approaching an unmitigable level of fatigue. This was likely due to the increased demand being placed on the motor control system as the torque of the arm on the shoulder joint increased as the arm extended. REFERENCES: [1] Yang et al. (2019). PLOS ONE, 14(12): 1-14. [2] Wu et al. (2005). J Biomech, 38(5): 981-992. [3] Hasanbarani, F. and Latash, M. L (2020). Motor Control, 24(2): 238-252.

S14.4 Impacts of fatigue, sex and age on control of upper limb repetitive tasks: the useful and the harmful

Julie Côté[1]
[1]*McGill University*

BACKGROUND AND AIM: Prolonged performance of repetitive upper limb tasks may expose active muscles to overload and injuries. The human body benefits from a high number of motor solutions that can produce multijoint patterns that are more or less variable from one movement to the next. We have observed that with repetitive motion-induced fatigue, some features of movement become more variable, seemingly a "good" adaptation, as this could help spread the effort amongst more muscles [1]. However, these findings are highly inconsistent and depend on the type of fatigue induced, as well as personal factors such as sex and age. The Uncontrolled Manifold (UCM) literature provides a mathematical framework to delineate variability as useful ("good") or harmful ("bad") towards task performance, and has been used to identify groups of individuals with motor dysfunction characterized by their "bad variability" [2]. In our recent studies, we have investigated the effects of fatigue, sex, and older age on patterns of useful vs harmful variability. METHODS: Three studies were conducted to analyze kinematic patterns of movement-to-movement variability using the UCM approach. In study 1, sex differences were assessed during the performance of a standing Repetitive Upper Limb Task performed (RULT) until fatigue [3]. In study 2, we measured the effects of fatigue localized at different joints on variability patterns during the same RULT. In study 3, we assessed the effects of old age on variability patterns during a seated RULT. RESULTS: Preliminary results show evidence to suggest few but some age and sex effects, with overall less motor variability between movements with old age, more variability with fatigue in women, and little evidence for group effects on "bad" variability. CONCLUSIONS: Follow-up analyses are needed to analyze whether personal factors other than age and sex may affect fatigability and motor variability. Results of our studies will be discussed within the context of the motor control literature, and ideas for further follow-up studies. 1. Côté JN (2014) Adaptations to neck/shoulder fatigue and injuries. Adv Exp Med Biol 826: 205-28. 2. Latash ML, Anson JG (2006) Synergies in health and disease: relations to adaptive changes in motor coordination. Phys Ther 86: 1151-60. 3. Hasanbarani F, Yang C, Bailey CA, Slopecki M, Côté JN (2021) Sex-specific effects of a repetitive fatiguing task on stability: Analysis with motor equivalence model. J Biomech 129: 110769.

S14.5 Use of minimally calibrated inertial motion units to efficiently detect fatigue during work-related upper extremity motor activities

Jason Bouffard[1], Béatrice Moyen-Sylvestre[2], Fabien Dal Maso[2], Étienne Goubault[2]
[1]Université Laval, [2]Université de Montréal

BACKGROUND AND AIM : Fatigue experienced during repetitive upper extremity work is often considered as a precursor of musculoskeletal disorders. An increasing number of lab-based studies have shown that fatigue leads to alterations in trunk and upper extremity kinematics. Detecting these changes using wearable technologies requiring minimal calibration may pave the way to prevention interventions aiming to control fatigue within workplaces. The aim of the present study was to explore the validity of different metrics computed with inertial motion units during fatiguing upper extremity activities. To minimise the need for sensor-to-segment calibration procedures and data temporal segmentation, which may be unsuitable for unconstrained assessment within workplaces, frequency-based analyses from gyroscope's and accelerometer's norms were chosen. METHODS : Twenty-four right-handed workers performed a repetitive pointing task (RPT) until they experienced significant shoulder fatigue (Borg scale 8/10). They also completed a tea filling task, which was closely related to their current job, before and after the RPT. Triaxial gyroscope and accelerometer data were collected from their dominant hand, forearm, upper arm as well as from their head, thorax and pelvis. For each segment, accelerometer's and gyroscope's norms were computed and transformed in the frequency domain using continuous wavelets. For each task, the average signal power in the low (0-3 Hz) and high (3-15 Hz) frequency range was compared for data collected before and after fatigue was induced. RESULTS : During the RPT, fatigue led to an increase in gyroscope and accelerometer signal power in the high frequency range for inertial motion units placed on proximal segments (i.e. pelvis, thorax, head and upper arm). Conversely, during the tea filling task, the high frequency signal was increased in distal segments (i.e. hand, forearm and upper arm). CONCLUSIONS : The study demonstrated the ability of inertial motion units to detect fatigue during upper extremity tasks, even without frequently used calibration procedures, which may prevent their use in the workplace. However, the task specificity of our results demonstrates the challenge of assessing the good segments in jobs involving a variety of upper extremity activities.

Symposium 15 – Neural control of trunk muscles in healthy and clinical conditions

S15.1 Neural interaction between upper limbs and the trunk and its clinical application

Shin-Yi Chloe Chiou[1], Shin-Yi Chloe Chiou[1]
[1]*University of Birmingham*

Background and aims: A voluntary contraction of muscles with one arm increases corticospinal drive to the contralateral resting arm, a phenomenon known as crossed facilitation. The concept of the crossed facilitation has been applied in motor training; for example, unilateral strength training resulted in improved strength in both trained and untrained muscles, and training the less affected arm improved motor function of the more affected arm in stroke survivors. Research has shown that crossed facilitation is present in trunk muscles induced by voluntary contractions of the arm muscles in healthy adults and in people with clinical conditions. However, whether the arm-trunk interaction can be used as a means of improving trunk function remains unknown. This presentation will cover the mechanisms underlying the arm-trunk interaction and its clinical application for trunk rehabilitation in people with spinal cord injury (SCI), a clinical population often experiences impaired trunk control. Methods: Using non-invasive transcranial magnetic stimulation (TMS) and high-voltage cervicomudallry electrical stimulation (CES), effects of voluntary contractions of the arm muscles on cortical and spinal circuits controlling erector spinae (ES) muscles were evaluated. Motor evoked potentials (MEPs) of the ES induced by TMS or CES were recorded using electromyography (EMG). Neuromuscular control of the ES muscles was evaluated using high-density surface EMG (HDsEMG) during dynamic balance tasks. Amplitudes of the activity and entropy were analysed. To objectively quantify volitional control of the trunk, movement trajectory of the trunk during dynamic balance tasks was recorded using a 3-D motion capture system and a force plate. Results: We found that amplitudes of ES MEPs increased during voluntary contractions of the arm muscles in both healthy adults and in individuals with incomplete SCI, suggesting that the arm-trunk interaction can still be present when a spinal cord is injured. Furthermore, our results demonstrate increased corticospinal drive to the ES muscle after single session of low-intensity, arm cycling exercise in healthy adults and the mechanisms are likely to involved cortical circuits. Moreover, data from individuals with SCI show increased corticospinal excitability of the ES muscles and greater activity of the bilateral ES muscles during the dynamic balance tasks after a home-based, arm cycling exercise training programme. There was also improvement in dynamic sitting balance after the training programme. Conclusions: Our work demonstrated the mechanisms underpinning the arm-trunk interaction in humans and, importantly, the influences of the arm cycling exercise on trunk control in individuals with SCI. This suggests the potential of improving trunk function via the use of arm cycling exercise after SCI.

S15.2 Neural control of cervical muscles in pain- free, experimental and chronic pain conditions.

Edith Elgueta-Cancino[1], Edith Elgueta Cancino[1]
[1]*University of Birmingham*

BACGROUND AND AIM: Control of the spine involves multiple networks/mechanisms at various levels of the sensorimotor system. The representation of the muscles in the somatotopically organised primary motor cortex (M1) provides an opportunity to explore the neural control of muscles and movements. However, this has been poorly described for neck muscles. This talk will review studies and present new evidence in corticospinal control of neck muscles, in control, experimental and chronic pain conditions. METHODS: Neurophysiological techniques such as transcranial magnetic stimulation (TMS) allows some insight into mechanisms of neural control of inter-muscle coordination in different conditions. RESULTS: Recent evidence suggests that organisation of M1 may influence the transition from acute to chronic conditions and changes in chronic condition. This may vary depending on the presentation or underlying mechanisms. We will review the current evidence regards neural control of neck muscles, optimal function, coordination (e.g spatiotemporal characteristics), and explore the differences in corticospinal excitability and M1 organisation in different pain conditions (e.g. experimental and clinical). DISCUSSION: Muscle training is able to induce neural changes at different levels of CNS (e.g. M1 organisation, motor unit behaviour). In the low back preliminary evidence describe the possibility of skill training to change the M1 organisation, but little is known regards neck muscle training. We will explore the latest evidence of the influence of neck muscle training (e.g. low load cranio-cervical coordination) in corticospinal excitability and M1 organisation.

S15.3 ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS EXHIBIT DECREASED COMMON NEURAL OSCILLATIONS IN THE LUMBAR PARASPINAL MUSCLES

Martin Simoneau[1], Martin Simoneau[1], Jean-Philippe Pialasse[1], Mercier Pierre[1], Jean-Sébastien Blouin[2]
[1]Université Laval, [2]The University of British Columbia

BACKGROUND AND AIM: Although adolescent idiopathic scoliosis is thought to be an orthopedic disorder, sensorimotor deficits resulting in asymmetric neural drive to the axial musculature have been proposed as contributing factors. Asymmetry in the vestibular control of spinal motoneurons can cause spine deformation reminiscent of idiopathic scoliosis in animal models. METHODS: To examine the neural control of axial muscles, we compared common oscillatory drive to bilateral lumbar muscles between 19 participants with adolescent idiopathic scoliosis and 19 healthy adolescents. We measured right and left paraspinal muscle activity during steady isometric back extensions at 15% or 30% of their maximum voluntary contraction. RESULTS: The variance in exerted force and symmetry in bilateral muscle activation were similar between groups. We estimated the strength of common oscillations between muscle motoneuron pools using intermuscular coherence. Compared to controls, participants with adolescent idiopathic scoliosis exhibited smaller intermuscular coherence between paraspinal muscles in the alpha and beta bands. To identify the cause of the observed decreased in intermuscular coherence, we quantified variability of electromyography power ratio and relative activation timing between the paraspinal muscle. Intermuscular phase between muscle oscillations across the alpha band demonstrated larger variability in adolescent with idiopathic scoliosis. The variability of the ratio of lumbar muscles power was similar between groups in the alpha and beta bands. CONCLUSION: Our results suggest that altered bilateral control of axial muscles characterized by increased variability in the timing of alpha oscillations may be linked to spine deformation in adolescents. Our findings provide a new perspective on neural factors associated with a common spine deformation, adolescent idiopathic scoliosis.

S15.4 Vestibular control of balance

Jean-Sébastien Blouin[1]
[1]University of British Columbia

BACKGROUND AND AIM: Vestibular sensory signals encode head movement and orientation in space, and provide vital information for the control of balance and navigation. The neural control of the trunk and appendicular musculature is influenced by descending signals originating from the vestibular system. Activating the vestibular endorgans using imposed head movements, however, also activates sensory afferents from other systems and consequently do not provide an isolated vestibular error signal. Although transmastoidal electrical vestibular currents have shown promise to provide an isolated error of vestibular origin, this approach activates all vestibular primary afferents such that the net signal resulting from such stimuli requires careful considerations. METHODS: Data from non-human primates have revealed that electrical stimuli applied percutaneously over the mastoid processes activate all vestibular primary afferents but exhibit a preferential activation of the irregular vestibular afferents and polarity-specific asymmetries. Using this knowledge, computational approaches enable estimates of the mechanical equivalent stimuli resulting from transmastoidal electrical stimulation. RESULTS: Based on predictions from a computational model, transmastoidal electrical currents can generate isolated vestibular error signals in humans to replicate a desired virtual motion and induce perceptions of head linear accelerations that depend on the orientation of the head in the gravitational field. Using distinct data processing approaches, noisy electrical stimuli can be used to characterize the task- (balance-movement transitions) and muscle-dependent (trunk vs. appendicular muscles) vestibular control of balance. When applied to healthy individuals, noisy vestibular stimuli induce vestibular responses up to 25 Hz in appendicular muscles and 70 Hz in neck muscles as well as discontinuities in the vestibular control of balance that enable transitions between states, i.e. balance-to-locomotion or shifts in postural orientation. CONCLUSION: This review of the mechanisms of action underlying transmastoidal electrical stimulation will provide a solid foundation for the continued use of this method to reveal mechanistic principles underlying the vestibular control of balance. The information presented will hopefully ensure the electrical vestibular stimulation technique is used properly and the data are interpreted correctly which will likely lead to novel biomedical applications of the modality to assess the neural control of the musculature in various health conditions as well as the future development of virtual reality approaches and partial neural prosthesis to enhance rehabilitation.

Oral Abstracts

Thursday June 23, 2022

Oral 1 - Rehabilitation

O1.1 The relationship between clinical examination measures and the fascia thickness surrounding trunk muscles or lumbar multifidus fatty infiltrations: An exploratory study

Christian Lariviere[1], Richard Preuss[2], Dany Gagnon[3], Sharon Henry[4]

[1]Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), [2]McGill University, [3]Université de Montréal, [4]The University of Vermont Medical Center

BACKGROUND AND AIM: Patients with chronic low back pain (CLBP) exhibit remodeling of the lumbar soft tissues. Muscle fatty infiltrations (MFI) and fibrosis of the lumbar multifidus (LuM) muscles, as well as thickness changes of the thoracolumbar fascia (TLF) and perimuscular connective tissues (PMCT) surrounding the abdominal lateral wall muscles, have been substantiated in these patients. Some ultrasound imaging (USI) parameters are sensitive to this remodeling. This study aims to explore whether these USI parameters are linked to (1) USI parameters of trunk muscle thickness and activation and (2) physical and psychological measures performed at the baseline clinical exam. These links may inform treatment. METHODS: USI measures, as well as a clinical examination comprising physical tests and psychological questionnaires, were collected from 78 patients with CLBP. The following USI dependent measures (USI-dep) were performed bilaterally: (1) LuM echogenicity (MFI/fibrosis) at three vertebral levels (L3/L4, L4/L5 and L5/S1); (2) TLF posterior layer thickness, and (3) PMCT thickness of the fasciae between fat and external oblique (PMCT _{Fat/EO}), between external and internal oblique (PMCT_{EO/IO}), between IO and transversus abdominis (PMCT_{IO/TrA}) and between TrA and intra-abdominal content (PMCT_{TrA/IA}). USI measures of trunk muscles function (thickness and activation) were considered as independent variables (USI-indep), along with physical tests related to lumbar stability (n = 6), motor control deficits (n = 7), trunk muscle endurance (n = 4), physical performance (n = 4), lumbar posture (n = 2), and range of motion (ROM) (n = 6). Psychosocial measures included pain catastrophizing, fear-avoidance beliefs, psychological distress, illness perceptions and concepts related to adherence to a home-based exercise program (physical activity level, self-efficacy, social support, outcome expectations). Six multivariate regression models (forward stepwise selection) were generated, using USI-dep measures as dependent variables and USI-indep/physical/psychosocial measures as independent variables (predictors). RESULTS: The six multivariate models (Table) included two to five predictors, explaining 62% (LuM echogenicity), 32-42% (TLF, PMCT_{Fat/EO}, PMCT_{EO/IO}) and 21-23% (PMCT_{IO/TrA}, PMCT_{TrA/IA}) of total variance, mainly using USI measures of trunk muscle function and physical test variables. One variable from the psychosocial domain - psychological distress (cognitive subscale) - contributed minimally to LuM echogenicity (7%). The level of physical activity during sports explained 13% of PMCT_{IO/TrA}. LuM echogenicity was mainly explained by pelvis (21%) and lumbar (17%) flexion ROM as well as lumbar lordosis (12%). CONCLUSIONS: These findings give some support to a conceptual model (doi:10.3390/ijms22147299) promoting a complex and interwoven impact for a range of biopsychosocial factors on local tissue remodeling of lumbar structures, although psychosocial and lifestyle factors were suggested to play a minor role here.

O1.2 ROTATOR CUFF RELATED SHOULDER PAIN: DOES THE TYPE OF EXERCISE INFLUENCE THE OUTCOMES? ? A RANDOMIZED CONTROLLED TRIAL

Marc-Olivier Dubé[1], Jeremy Lewis[2], François Desmeules[3], Jean-Sébastien Roy[1]
[1]Université Laval, [2]University of Hertfordshire, [3]Université de Montréal

BACKGROUND AND AIM: Rotator cuff related shoulder pain (RCRSP) is the most common shoulder disorder. Education and exercise are recommended interventions for the management of RCRSP. Despite this, 30% of people have no significant change in their symptoms, regardless of the intervention undertaken. This lack of effectiveness could be explained by a poor choice of exercise or other pain-related factors such as kinesiophobia, catastrophisation or lower levels of pain self-efficacy. These prolonged symptoms need to be better managed as they can lead to detrimental consequences such as absenteeism from work, reduced quality of life and participation, and high associated healthcare costs. The main objective of this project was to compare the short, mid and long-term effects, in terms of symptoms and functional limitations, of 3 different ways (education, strengthening + education, motor control + education) of delivering shoulder management in individuals with RCRSP. METHODS: 123 adults presenting with RCRSP for more than 3 months took part in a 12-weeks intervention. They were randomly assigned to 1 of 3 intervention groups (education, strengthening + education, motor control + education). Symptoms and functional limitations were evaluated at baseline and at 3, 6, 12 and 24 weeks using the QuickDASH (primary outcome) and Western Ontario Rotator Cuff Index (WORC). Since one intervention targeted shoulder control, ultrasound measurements of acromiohumeral distance (AHD) at rest and at 60° of active abduction were performed at 0 and 12 weeks to estimate the humeral head position in relation to the acromion. Nonparametric Analysis for Longitudinal Data were used to compare effects of the three programs on the outcomes. RESULTS: For QuickDASH and WORC, analyses showed significant time ($p<0.001$) and group X time interactions ($p=0.013$ and 0.031, respectively); greater improvement in time was observed for the motor control group compared to the two other groups. Mean QuickDASH change scores reached the MCID at 3 weeks for the motor control group and at 6 weeks for the other two groups, while mean WORC change scores reached the MCID at 3 weeks for all three groups. There was a significant group X time interaction ($p = 0.05$) for AHD at 60° of abduction (mean between-group differences ranging from 0.09 to 0.11 cm) highlighting a significant increase at 12 weeks for the motor control group compared to the other groups. CONCLUSION: All three interventions led to statistically and clinically important improvements. Motor control exercises were associated with larger improvement in symptoms and functional limitations, although they did not exceed the MCID. Further research should look at the value of providing stratified care by identifying individuals who would only need education and those who would benefit from the addition of motor control exercises or strengthening exercises.

O1.3 Integrating computer vision with electromyography for semi-autonomous control of robotic limbs

Milia Hasbani[1], Deren Barsakcioglu[1], Rachel Azulay[1], Moon Ki Jung[1], Dario Farina[1]
[1]Imperial College London

BACKGROUND AND AIM: Grasping with an active prosthetic hand can be a complex process leading to non-intuitive control where users cycle through grasp types using buttons, co-contraction, or thresholding. The main challenge in these systems is the complexity of predicting the intended grasp type from the user. This prediction is usually based on electromyography (EMG) signals recorded from the stump. In addition to EMG, the motor intention prediction can be improved with the addition of sensors to simulate biological senses, such as vision. Here, we aim to introduce a shared control strategy based on high-density surface EMG (HDsEMG) and a computer vision system. The HDsEMG is used for

the control of 2 degrees of freedom of the prosthetic wrist while the computer vision system analyses visual inputs to select a grasp type which is applied upon the closing of the hand. As a preliminary step in developing an integrated online system, all system components were studied offline separately. METHODS: HDsEMG (Quattrocento, OT Bioelettronica) and optical marker motion capture (SMART DX, BTS Bioengineering) were recorded concurrently from the lower arms of 8 subjects performing a series of wrist and hand movements in individual, sequential, and simultaneous degrees of freedom. Features extracted from the EMG signal and kinematics obtained from the motion capture were used to train regression and classification models to predict the kinematics of wrist movements and opening and closing of the hand, respectively, from the EMG recordings. EMG features (root mean square (RMS), cross correlation, x and y variogram) were compared to determine the optimal prediction strategy. In parallel, a computer vision system was developed and trained on an image dataset [1] to predict one of four grasp types (general, spherical, pinch, tripod) from the image of an object. The algorithm consists of passing a pre-processed image through a U-net Convolutional Neural Network to generate a level-set mask which is classified into a grasp type through K-Means clustering. RESULTS: The offline results show that regression from the EMG RMS feature yielded the best results for estimating wrist kinematics (median r^2 score of 0.75-0.85). Classification with a Support Vector Machine achieves 80% and 96% recall for closing and opening the hand respectively with the EMG RMS feature. The offline computer vision algorithm correctly classified 88% of grasp types when tested on 5,008 unseen images. CONCLUSIONS: The computer vision system is successful in generalising to unseen objects, which makes it suitable for use in a prosthetic hand. These results determine robust strategies for further work in the development of a combined online system that integrates state of the art myocontrol and computer vision. REFERENCES: 1. A. Depierre, E. Dellandrea, and L. Chen, "Jacquard: A Large Scale Dataset for Robotic Grasp Detection" in IEEE International Conference on Intelligent Robots and Systems, 2018.

O1.4 Physical and psychological effects of combined motor control and isolated lumbar extension exercise versus general exercise for chronic low back pain: a randomized controlled trial

Alexa Roussac[1], Meaghan Rye[1], Neda Naghdi[1], Brent Rosenstein[1], Luciana Macedo[2], James Elliott[3], Veronique Pepin[1], Richard DeMont[4], Michael Weber[5], Geoffrey Dover[1], Maryse Fortin[4]
[1]Concordia University, [2]McMaster University, [3]University of Sydney, [4]Concordia, [5]McGill University Health Centre

BACKGROUND AND AIM: Exercise is the most common treatment approach for patients with chronic low back pain (LBP). While the physical aspect of LBP is typically the focus in the management of LBP symptoms, psychological factors should also be considered given their known negative influence on recovery. Motor control exercises and general strengthening exercises are two commonly used exercise therapies for chronic LBP, yet few studies have specifically examined whether these exercise interventions are effective to improve both physical and psychological factors in chronic LBP. Therefore, the purpose of this trial was to compare the effectiveness of combined motor control exercises and isolated lumbar extension exercise (MC ILEX) versus general strengthening exercise (GE) on pain, disability, and psychological factors in patients with chronic LBP. METHODS: This study was a prospective registered randomized controlled trial (NTCT04257253). A total of 47 participants with moderate to severe LBP (aged 18-65 years old) were randomly assigned to either the MC ILEX or GE group. Participants in both groups received 24 supervised exercise sessions (1 hour each), 2x/week over 12-weeks. Outcome measures were obtained at baseline, 6-week and 12-week and included pain intensity (Numerical pain Rating Scale, NPRS), disability (Oswestry Disability Index, ODI), symptoms of

depression and anxiety (Hospital Anxiety & Depression Scale, HADS), pain catastrophizing (Pain Catastrophizing Scale, PCS), Kinesiophobia (Tampa Scale of Kinesiophobia, TSK) and sleep disturbances (Insomnia Severity Index, ISI). Repeated measures ANOVA was used to assess the main effects of group, time, and group*time interaction for each outcome measure. RESULTS: There were no significant differences between groups (Table 1) for any outcome at any time points (main effect of group, time, and group*time interaction all >0.05). However, participants in both groups had statistically significant improvements in NPRS (p <0.001), ODI (p<0.001), and TSK(p=0.005) scores from baseline to 12-week (Table 1). Participants in the MC ILEX group also had significant improvements in PCS (p=0.04) scores. For NPRS (p=0.018) and ODI (p=0.002), significant improvements were also observed between baseline and the 6-week. There were no significant differences in HADS or ISI scores at any time points. CONCLUSIONS: Our findings indicate that MC ILEX and GE have similar positive effects in patients with chronic LBP. Both exercise interventions were effective to improve pain, disability, and psychological factors following a 12-week intervention, with pain and disability improving as early as 6 weeks. Given that there was no significant difference between groups, prioritizing adherence to similar exercise intervention programs for patients with chronic LBP may lead to patients-reported benefits in pain, disability, and psychological factors.

O1.5 Metrological qualities of a new surface EMG based-index in Autosomal Recessive Spastic Ataxia of Charlevoix-Saguenay

Olivier Audet[1], Isabelle Lessard[2], Mathieu Bielmann[3], Cynthia Gagnon[4], Raphaël Saint-Gelais[2], Hubert Racine[3], Rubens A. da Silva[5], Luc J. Hébert[6]

[1]Center for Interdisciplinary Research in Rehabilitation and Social Integration (CIRRIS), [2]Groupe de recherche interdisciplinaire sur les maladies neuromusculaires (GRIMN), [3]Center for Interdisciplinary Research in Rehabilitation and Social Integration, [4]Université de Sherbrooke, [5]Université du Québec à Chicoutimi, [6]Université Laval

BACKGROUND AND AIM Autosomal recessive spastic ataxia of Charlevoix-Saguenay (ARSACS) is a neuromuscular disease for which lower limb muscle impairments is one of the most disabling features. Research and clinical observations suggest that abnormal muscle activation of the antagonist muscles combined with spasticity could lead to a loss of mobility. However, the pathophysiological mechanism related to this abnormal muscular pattern has not really been studied. This study aims to determine the construct validity and intrarater reliability of a new surface electromyography (EMG) based-index, namely muscle co-activation ratio (CoA-r). METHODS The knee muscle EMG activity of 51 ARSACS (age: 36.0 ± 11.0 years; 49.0% of men) and 9 control healthy participants (age: 36.4 ± 14.7 years; 44.4% of men) was measured during three functional tasks (knee flexion and extension and sit-to-stand). The muscle activation level (raw EMG signals) was measured using an EMG system (TrignoTM EMG, Delsys Incorporated, USA) with wireless surface EMG sensors with pre-amplified signals (sensors resolution 16 bits; EMG sampling rate 1925.93 Hz; EMG bandwidth 20±5 - 450±50 Hz; Common Mode Rejection Ratio 80 dB at 60 Hz). For each task, an antagonist CoA-r was calculated using the area under the curve (AUC) of the EMG signal across time-series task as follows: AUC of EMG antagonist muscles/AUC of EMG agonist muscles. The intrarater reliability of the EMG CoA-r was calculated using intra-class correlation coefficients (ICC) to assess the agreement of data measured across three consecutive trials for each task. Movement kinematic parameters were also compared between trials to verify if the task was performed under similar condition. A priori, we have made the assumptions that the EMG CoA-r should be able to distinguish the non-affected participants (control) from the ARSACS ones, and between

ARSACS participants according to their level of mobility (walkers not using a walking aid, walkers using a walking aid, and non-walkers using a wheelchair). RESULTS The study's findings partially support the construct validity of the EMG CoA-r. Compared to control, the knee antagonist muscle coactivation ratio was significantly higher in ARSACS participants ($p<0.05$). However, this ratio does not seem to be sensitive enough to discriminate between all levels of mobility in ARSACS group according to the classification used in this study. For the three tasks, the ICC reliability estimates were excellent (≥ 0.96) for the EMG CoA-r within the same session while for the kinematic knee parameters, the ICCs (95% confidence interval) ranged between 0.83 (0.70 - 0.90; moderate) and 0.99 (0.99 - 1.00; excellent). CONCLUSIONS The use of an EMG-based index (CoA-r) with adequate metrological properties to assess muscle coactivation in ARSACS is a promising avenue. Such outcome may allow to better document muscle impairments in neuromuscular diseases to develop more targeted interventions.

O1.6 Greater paraspinal muscle activity on the convex than concave side is more prevalent for adolescents with single right progressive idiopathic scoliosis. A narrative review of surface EMG studies.

Phoebe Ng[1], Andrew Claus[2], Maree Izatt[3], Peter Pivonka[3], Kylie Tucker[4]
[1]KK Women's and Children's Hospital/ The University of Queensland, [2]The University of Queensland/ Royal Brisbane Children's and Women's Hospital, [3]Queensland University of Technology, [4]The University of Queensland

BACKGROUND AND AIM: Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional spinal deformity occurring between ages of 10 to 18 years, and is also associated with morphological and physiological changes in paraspinal muscles. We present a synthesis of published evidence for and against asymmetrical paraspinal muscle activation in AIS. METHODS: PubMed and Embase databases were searched using terms: adolescent idiopathic scoliosis AND electromyogra* (EMG). RESULTS: N=94 studies were screened for eligibility. Outcomes from 16 studies were included. For EMG onset, one of two studies reported earlier muscle activation on the convex compared to concave side of the spine at the curve apex and lower end vertebral level (most tilted vertebra below the apex). Asymmetrical activation was more prevalent in those with progressive than non-progressive AIS. For EMG amplitude, 136 outcomes from 15 studies were included. In addition to reported significance (Figure 1A), ratios of convex/concave activity were derived from the data to enable synthesis of results. Eighty-five outcomes supported no-small activation asymmetry (Figure 1B-Green, Black, Yellow), 43 outcomes supported convex>concave activation (Figure 1B-Purple), and 8 outcomes supported concave>convex activation (Figure 1B-Red). Greater activity on the convex than concave side was more commonly observed at the curve apex level, in people with single right thoracic progressive curves. Asymmetrical amplitude of activation was more prevalent during <i>static-postural</i> compared to <i>isometric, isokinetic and mechanical perturbation</i> tasks. CONCLUSION: Given data from often very diverse participants were grouped, it is likely that the asymmetry is under-reported. In the 16 studies evaluated, there were inconsistent reports of electrode placement and data processing, another 13 studies were excluded due limitations in their description of EMG measures that prevented comparison of timing or amplitude of activity between convex and concave sides. As such, further research is needed to determine the relationships between muscle activity asymmetry and spinal curve parameters. For future studies recording EMG in those with AIS, we recommend (i) reporting of non-normalised amplitude data as well as data normalised to maximum voluntary contraction, (ii) use of B-mode ultrasound to facilitate electrode placement within test muscles boundaries, (iii) placement of electrodes at the level of apex,

upper, and lower end vertebra of spinal curves, (iv) open access to individual data, and (v) accurate reporting of electrode placement and data processing. To facilitate quality meta-analysis, it is critical that participant age, sex, skeletal maturity (i.e. Risser score), curve characteristics: side, single or double curve, Cobbs angle, apex level, and curve progression status, are reported. To enable comparison between AIS participants and the equivalent side of their matched control group, data from "convex-equivalent" and "concave-equivalent" sides are required for matched participants with symmetrical spines who contribute to a control group.

O1.7 A Textile-based Electrode System for Self-administered Phantom Limb Pain Treatment in the Home Environment

Anna Björkquist[1], Morten Kristoffersen[2], María Muñoz-Novoa[2], Max Ortiz-Catalan[3], Leif Sandsjö[1], Li Guo[1]
[1]University of Borås, [2]Gothenburg University, [3]Chalmers University of Technology

BACKGROUND AND AIM: People with limb loss might be affected by Phantom Limb Pain (PLP) in the amputated limb. One treatment to reduce PLP is phantom motor execution (PME). PME can be facilitated by decoding motor volition using myoelectric pattern recognition to then control virtual limbs and games to re-engage central and peripheral circuits involved in motor control (Ortiz-Catalan 2016). PME can be used as a home-based treatment where patients benefit from staying in the comfort of their own home and thus increasing training opportunities (Lendaro 2018). One challenge with home-based PME is the placement of single-use electrodes, which is both time-consuming and difficult to do without the assistance of a physiotherapist. In this study, we investigate the effectiveness of a textile-based electrode matrix system, named textrode-band, as an alternative to the several single-use electrodes needed to record myoelectric signals to perform PME and ultimately to treat PLP at home. METHODS: In an ongoing trial, six participants will be provided with and trained to use the textrode band to perform PME at home. The study consists of three intervention phases: 1) pre-intervention phase, where participants are trained to use the system at home (Fig.1), 2) Phase I, where participants train at home following a schedule with on-call support as needed and 3) Phase II, train at home at their own discretion without support. PLP is evaluated using the Q-PLP questionnaire after each session, addressing the intensity, character, duration, and frequency of the pain, how the pain affects sleep, and how the participant perceives the pain. At the end of intervention phases I and II, semi-structured interviews are performed to evaluate the users' experiences from the treatment enabled by the textrode-band. RESULTS: To date, we have gathered preliminary results from the first participant who has lower limb loss. The control of the virtual leg is good (> 90% online accuracy) demonstrating that textrode-band is a feasible alternative to traditional single-use electrodes for performing PME. The preparation time per session to wet and wear the textrode-band is 15 minutes (compared to 45 minutes with a single-use electrodes setup). The participant expressed that he likes the textrode band, but that the need to wet the band is an inconvenience/drawback. Future studies will focus on making the wetting process easier or using other materials with enough conductance in dry conditions. CONCLUSIONS: In this study, we introduced the concept of using a textile-based electrode system performing PME for the purpose of alleviating PLP. The preliminary results are favorable, indicating a potential for the PLP treatment to be fully self-administered. A home-based protocol will reduce visits to clinical sites. This means not only improved quality of life for these patients also a substantial reduction of healthcare and service costs.

Oral 2 – Muscle Synergy

O2.1 To what extent does unilateral chronic Achilles tendinopathy affects lower extremity muscle synergies during gait at natural and fast speeds?

Mathieu Lalumière[1], Daniel Bourbonnais[1], Michel Goyette[2], Sarah Perrino[1], François Desmeules[1], Dany Gagnon[1]

[1]Université de Montréal, [2]Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal

BACKGROUND AND AIM: Chronic Achilles tendinopathy (AT), through alteration of Achilles tendon biological integrity, presence of localized pain and central adaptations, muscle synergies (MS) during gait may be affected. This study compares MS attributes between the asymptomatic and symptomatic lower limbs (LL) of individuals with unilateral AT during gait at natural and fast speeds. METHODS: Twenty-eight participants walked on an instrumented treadmill at natural (1.3 m/s) and fast (1.6 m/s) speeds while bilateral surface electromyography (EMG) of eight LL muscles was recorded. Individualized EMG activation profiles were time- and amplitude-normalized for three consecutive gait cycles. MS were extracted using non-negative matrix factorization (NNMF) algorithms. MS were characterized in terms of number, composition (i.e., weighting of each muscle), and profile (i.e., duration and amplitude). For each participant, paired Student's t-tests assessed MS muscle weighting differences between sides whereas Pearson correlation coefficient characterized similarity of individualized EMG and MS activation profiles. RESULTS: The presence of AT had limited effects on bilateral MS attributes during gait at natural and fast speed. Two to five MS were extracted bilaterally using NNMF for all eight muscles for each side. In most participants, four MS with a specific set of predominantly activated muscles were extracted at the asymptomatic and symptomatic LL across natural (71% and 61%) and fast (54% and 50%) speeds, respectively. Individualized EMG activation profiles were highly similar between the both LL (r= 0.970 to 0.999) (Fig.1-A). As for the MS attributes, relatively similar temporal activation profiles (r= 0.988 to 0.998) and muscle weighting ($p<0.05$) were found between LL for all four MS (Fig.1-B&C). Though faster walking increased the number of merged MS for both LL, it did not significantly alter MS symmetry. No unilateral alteration in the motor recruitment strategy of the hip or knee muscle stabilizers was observed during the support phase for the symptomatic side. Likewise, no motor recruitment strategy difference was observed at the ankles during the pushoff phase for the symptomatic side. This last adaptation was anticipated mostly to reduce the tensile force transiting through the symptomatic Achilles tendon. CONCLUSIONS: Corticospinal neuroplastic adaptations linked to chronic unilateral AT may explain the preserved quasi-symmetric LL motor control during gait at natural and fast speeds among adults with chronic unilateral AT. Increasing LL muscular demand further (e.g., running, jumping) may have altered the ability of individuals with chronic AT to modulate excitatory and inhibitory control of their LL muscles. The paradigm shift in current tendon-focused rehabilitation strategies deserve continued attention to best address corticospinal neuroplasticity adaptations.

O2.2 Cortical contributions to locomotor primitives in toddlers and adults

Coen Zandvoort[1], Andreas Daffertshofer[1], Nadia Dominici[1]

[1]Vrije Universiteit Amsterdam

Deciphering the neural organization underlying muscle synergy formation is timely and urgent. The early development of these synergies may shed light on this organization [1]. In newborns' stepping, two muscle synergies with alternating sinusoidal-like patterns, peaking at mid-stance and mid-swing, can be identified [1]. They are likely to arise from brainstem and local spinal circuitries. At the onset of independent walking in toddlers, four muscle synergies can be observed: two supplementary muscle

synergies that peak around the bilateral foot contacts emerge and are added on top of the two that resemble the neonatal ones [1]. Such developmental changes may be the result of structural and functional developments of the motor cortex and cortico-spinal tract. The differential muscle synergy organization suggests that the supplementary synergies have a counterpart in motor areas. By contrast, the two synergies that resemble newborn stepping are not expected to have a cortical representation. We focused on two groups, both expected to display four muscle synergies: eighteen toddlers (mean±SD; 19.7±2.0 months) and adults (21.8±6.4 years). Participants were asked to walk over-ground and on a treadmill at comfortable speeds. We recorded muscular activity of trunk and leg muscles using 24-channel electromyography (EMG) and cortical activity using 32-channel electro-encephalography (EEG). For both toddlers and adults, multivariate EMG was decomposed using non-negative matrix factorization into four muscle synergies. We employed DICS-beamforming to source localize cortical areas that exhibited maximal coherence between EEG and (proxies of the) muscle synergies (proxies because we included their high-frequency components). We also estimated time-frequency cortico-synergy coherence. Both analyses were spectrally limited to the beta frequency band (13-30 Hz) which is known for its contribution to gait control. Significant beta-band sources were limited to the two supplementary synergies time-locked to bilateral foot contact in toddlers and adults alike. Coherences with these synergies were primarily located around (primary) motor and sensory areas of the cortex. Adults exhibited more frontal coherence than toddlers, as reflected in between-group contrasts. Time-frequency coherences between motor cortex and these two synergies revealed cycle-dependent modulation with peak coherences aligned to the synergy amplitudes and double support phases. Between-group statistics revealed more focal coherence around the double support phases in adults compared to toddlers. These findings support the view that locomotor muscle synergies rely on distinct neural circuitries. In our study, cortical counterparts of the muscle synergies were only found for the two supplementary synergies, and not for the congenital ones. The use of cortico-synergy coherence analysis enabled us to dissociate cortical and sub-cortical processes involved in the formation of muscle synergies. [1] Dominici, N., et al. (2011). Science, 334(6058), 997-999.

O2.3 Independent walking is accompanied by cortico-synergy coupling

Coen Zandvoort[1], Andreas Daffertshofer[1], Nadia Dominici[1]
[1]*Vrije Universiteit Amsterdam*

When independent walking emerges, congenital muscle synergies are maintained and new ones appear [1]. Arguably, the two sets of synergies rely on different neural circuitries. Although utilization of brainstem and spinal structures appear pivotal for the congenital synergies, the supplementary synergies may capitalize on cortical networks. The emergence of the latter set coincides with the appearance of cortico-synergy coupling. Here, we present a longitudinal assessment of cortico-synergy coherence throughout early locomotor development. We hypothesized that the appearance of the supplementary synergies when babies do their first steps coincides with an increase in such coherence. We recorded babies at four timepoints. They visited our lab at around 5 months (16 babies; age (A): 5.7±0.9 (mean±SD in months); time since onset of walking, i.e. walking age (WA): -7.2±1.7), around 10 months (24 babies; A: 10.4±0.6 and WA: -2.8±1.8), first steps (19 babies; A: 13.7±2.0 and WA: 0.3±0.1) and 6 months after the first steps (24 babies; A: 19.6±1.9 and WA: 6.3±0.9). Depending on their age, babies performed either only treadmill walking or both over-ground and treadmill walking. We recorded 32-channel electro-encephalography (EEG) and trunk and leg muscles using 24-channel electromyography (EMG). Non-negative matrix factorization served to decompose multivariate EMG into four muscle synergies per group. To compare the synergy sets across timepoints we fixed the number to four for every group. Beta-band coherence (13-30 Hz) between EEG and virtual patterns (high-frequency estimates of the synergy patterns) was source localized using DICS-beamformers. We also computed time-resolved coherence as a function of the gait cycle between the spatially filtered EEG and virtual patterns. Beamformed and time-resolved coherences were subjected to voxel-wise general linear models to elucidate the factors Synergy (Congenital and Supplementary) and Timepoint (5 months, 10 months, First steps, and 6 months after the first steps). The main effect of Synergy was significant in both beamformed and time-resolved coherences. Coherence was clearly higher in the emerging synergies compared to the congenital synergies. The Synergy X Timepoint interaction revealed differential coherence development for the two synergy sets. Between the 10-months and first-steps groups, coherence increased considerably for the emerging synergies whereas the change for the congenital ones was negligible. The cortical source was localized around left sensorimotor areas. Time-resolved coherences showed this to be particularly pronounced during double support phases. The first independent steps in toddlers are accompanied by selective increases in beta-band coherence for the supplementary synergies. Such rises around the onset of walking can be seen as a sign of more powerful interactions between the cortex and these two synergies. It remains to be seen whether this is a sequence of causal events with independent walking preceded by cortical reorganizations enabling the emergence of the two supplementary synergies. [1] Dominici, N., et al. (2011). Science, 334(6058), 997-999.

O2.4 Neck Muscle Network Topology Analysis in People with Chronic Neck Pain

David Jimenez-Grande[1], Eduardo Martinez-Valdes[1], Deborah Falla[1]
[1]*University of Birmingham*

BACKGROUND AND AIM: Neuromuscular impairments are frequent clinical features in patients with chronic neck pain (CNP); studies using electromyography (EMG) have revealed altered behaviour of the neck muscles (e.g., increase co-activation, reduced specificity of activity, delayed onset) in patients with CNP compared to asymptomatic individuals. Based on this knowledge, we hypothesized that the connectivity between neck muscles will be modified in people presenting with CNP. Verification of this hypothesis would provide further evidence of common neuromuscular adaptations in people with CNP. This paper uniquely investigates how multi-muscle coordination is modified in people with CNP through intermuscular coherence analysis applied to EMG data acquired during neck flexion. METHODS: Ten asymptomatic individuals and 10 people with CNP were recruited for this study. Participants performed three neck flexion contractions whilst seated in a Multi-Cervical Unit (BTE Technologies, Inc). EMG signals were acquired from the upper trapezius (UT), splenius capitis (SC), anterior scalene (AS) and sternocleidomastoid (SCM) muscles bilaterally. Intermuscular coherence was used to map functional interactions between multiple muscles by the calculation of magnitude squared coherence (MSC). MSC generates a value of connectivity strength for each pair of filtered EMG signals at a specified frequency band, resulting in a weighted adjacency matrix per participant. This matrix is then thresholded in order to emphasize only significant connections and remove those that can obscure them. Once the average coherence matrix was obtained for each group, the connectivity between muscles can be represented graphically. Four frequency bands were considered in the calculation of the connectivity matrices: δ (1-4 Hz), θ (4-8 Hz), α (8-12 Hz) and β (12-25 Hz). Functional networks were compared based on strength (ST) and betweenness centrality (BC) features. BC identifies hot points of high information traffic, and it is calculated as the proportion of shortest paths between all node pairs in the network that passes through a given index node. ST is the sum of weights of links connected to the node that provides information about how strong the connections are between muscles. RESULTS: BC showed significance in the δ band between asymptomatic individuals and those with CNP ($p = 0.012$). In contrast, ST did not reach statistical significance between groups ($p = 0.068$). No significant differences were found in other frequency bands. In addition, neck muscle networks in this frequency band show graphical differences, that is, the network for those with CNP was characterised by a lack of connections and very localized connectivity for the AS and SC muscles (Fig. 1). In contrast, the network for the asymptomatic group has more connections and a more evenly distributed synchronisation between muscles. CONCLUSIONS: These results confirm altered muscle synergies in people with CNP compared to asymptomatic individuals. Differences were observed in the δ band which is the most relevant band for the generation and control of force.

O2.5 Muscle synergies for highly variable human manipulations

Hiroki Saito[1], Hikaru Yokoyama[2], Atsushi Sasaki[2], Tatsuya Kato[2], Kimitaka Nakazawa[2]
[1]The Tokyo University of Technology, [2]The University of Tokyo

Background and Aim: Manipulations require complex upper-limb movements in which the central nervous system (CNS) must deal with many degrees of freedom. Literature suggests that the CNS recruit weighted muscle groups, commonly referred to as muscle synergies to simplify the production of movements. However, the exact neural mechanism underlying muscle synergies to control a wide array of manipulations is not fully investigated. The purpose of this study was to explore the muscle synergies during highly variable rudimentary and fundamental manipulation tasks by recording the activation of major upper limb muscles. Methods: Eight healthy volunteers (aged 21-35 years, all men) participated in the study. Each participant provided written informed consent for participation in the study. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee. For each participant, the electromyographic (EMG) activities of 20 muscles across the shoulder, elbow, and wrist and fingers were measured during 24 manipulation tasks including multidirectional reaching, several types of grasping and throwing and catching a ball. Non-negative matrix factorization (NMF) applying to the EMG of each motor task and the concatenated EMG data of all motor tasks was used to identify all-task muscle synergies and single-task muscle synergies, respectively. The variance accounted for (VAF) of > 90 %, as a measure for the quality of EMG reconstruction, was used to determine the optimal number of muscle synergies for each data set. Results: The NMF identified that upper limb muscle activities in the control of 24 rudimentary tasks such as reaching and grasping and fundamental tasks such as throwing and catching were successfully reconstructed by one to five single-task muscle synergies. Furthermore, the NMF identified nine basic units of muscle synergies derived from the concatenated EMG data of all motor tasks. We found a high similarity between muscle synergies of each of the 24 tasks and various combinations of nine basic unit muscle synergies in a single and/or merging state. Discussion: We suggest that the CNS may flexibly select and modify the degree of contribution of the nine basic units of muscle synergies to overcome different mechanical demands of a variety of manipulations. Future works need to clarify this hypothesis by a direct evaluation of the CNS loci such as involving neural spike trains or electroencephalography.

O2.6 Sex-specific effects of fatigue on muscle synergies in a repetitive pointing task

Yiyang Chen[1], Chen Yang[1], Julie Côté[1]
[1]McGill University

BACKGROUND AND AIM: Control of multi-joint movements is achieved by complex interactions between the central nervous and musculoskeletal systems. Studies have shown that males and females utilize different motor control strategies in response to fatigue during a repetitive pointing task (RPT). However, how fatigue affects the spatiotemporal patterns of synergic muscles of both sexes remains unknown. METHODS: Fifty-six healthy participants (29 females) were recruited. The surface electromyographic activity of upper trapezius (UT), anterior deltoid (AD), biceps brachii (BIC), and triceps brachii (TRI) were recorded (Delsys©) during a fatiguing RPT, consisting of repetitively moving the entire arm in a horizontal plane between two targets placed at shoulder height in a forward/backward motion. The task was terminated when perceived neck/shoulder exertion reached 8/10 on a Borg CR10 scale. The first and last 30 seconds of the task were defined as non-fatigue (NF) and fatigue-terminal (FT) conditions, respectively. Activation coefficient (C), synergy weight (W), and variance accounted for (VAF) were calculated by using non-negative matrix factorization method. Two-way (fatigue×sex) repeated-measures ANOVA was used to examine C, W, and VAF. Statistical parametric mapping on ANOVA was used to compare C between NF and FT. RESULTS: Two synchronous muscle synergies were extracted (VAF>0.9) in both sexes. Generally, each synergy involved four muscles. Synergy 1 was active during the entire task, mostly in the beginning of backward pointing. This synergy facilitated the stabilization of the shoulder. Synergy 2 was mainly active at the beginning phase of forward pointing and the latter phase of backward pointing. This synergy was mainly responsible for the flexion and extension of the elbow. As for synergy 1, there were no effects of sex or fatigue on W. Temporally, fatigue led to a significant increase in C in the forward pointing deceleration phase in both males and females (p=0.049). This indicated that both sexes had higher muscle synergy activation amplitude after fatigue in forward pointing deceleration phase when stabilizing the elbow. As for synergy 2, there were significant main effects of sex and fatigue on W. W of BIC was significantly higher in females than in males (p=0.04). After fatigue, a significant increase of W was found in both sexes (p=0.032). The C increased significantly during backward pointing acceleration (p=0.034) and deceleration phases (p=0.025). CONCLUSIONS: Overall, the findings suggest that fatigue induced by RPT changed muscle synergy activation and weight of selected shoulder muscles, in a sex-specific way, notably, with females utilizing more of their BIC in response to fatigue compared to males during elbow extension and flexion. These findings are in line with those of previous studies showing differences in how men and women utilize their shoulder and elbow muscles to adapt to RPT-induced fatigue, and could help explain sex-specific mechanisms of fatigue and injury development.

O2.7 Static force feedback training recruiting muscle synergies improves strength and coordination of the paretic lower extremity and mobility in participants with stroke

Daniel Bourbonnais[1], Mathieu Lalumière[1], Michel Goyette[1]
[1]*Université de Montréal*

BACKGROUND AND AIM: Controlled static exertion performed in the sagittal plane on a transducer attached to the foot requires coordinated moments of force at the different joints of the lower extremity and recruit in some directions, muscular activation patterns similar to synergies previously identified during sub-cycles of gait in both healthy and stroke participants (Lalumière et al., 2020; Bourbonnais et al., 2021). The objective of the study is to determine, using a single case design, if a training program based on static directional exertions of the lower paretic extremity and static plantarflexion results in improved mobility in people with hemiparesis. We also verified if changes in maximal voluntary effort (MVE) and in the accuracy required to perform the exertion exercise are observed following training. METHODS: Four male participants aged between 50 and 74 (59.3± 8.2) years with hemiparesis as a result of a stroke participated in the study. The training program consisted of 37 sessions distributed over 20 weeks across 4 periods (baseline, training, withdrawal, and follow-up). During training, the subjects were instructed to perform exertion exercises in eight successive directions in the sagittal plane. The maximal exertion produced by the subjects was measured at the first session of every week and used to rescale the requested directional exertion tasks. During the first session of a given week of training, 8 repetitions were requested and 12 repetitions for the second and third sessions of the week. Two levels of exertion (i.e., directional exertion) were used during the training period and were increased every 2 weeks (20 and 40% weeks 1- 2, 25-50% weeks 3-4, and 30 and 60% weeks 5-8). However, the levels of exertion remained constant for the plantarflexion exercise. At each of the 37 sessions, functional mobility was assessed using GAITRite® and the Timed Up and Go (TUG) test. Tau statistics were used to evaluate the effect of training on mobility before and after training. Measures of MVE and the accuracy of directional exertion were compared before and after training using ANOVAs. RESULTS: Directional exertion training in hemiparetic subjects resulted in improvement in MVE ($p < 0.040$) and task performance accuracy ($p < 0.001$). Hemiparetic subjects also demonstrated significant improvements in gait velocity ($p < 0.032$) and in the TUG test ($p < 0.022$) following training. CONCLUSION: It is suggested that a directional force-feedback training program, which improves strength and coordination of the lower extremity, provides the opportunity to practice muscle activation patterns similar to synergies normally recruited during gait and contribute to the improvement in mobility.

Oral 3 - Fatigue

O3.1 Enhanced availability of serotonin reduces voluntary muscle activation during high-intensity, but not during low-intensity, fatiguing contractions

Tyler Henderson[1], Janet Taylor[2], Jacob Thorstensen[3], Murray Tucker[4], Justin Kavanagh[1]
[1]Griffith University, [2]Edith Cowan University, [3]University of Queensland, [4]Barwon Health

Prolonged release of serotonin (5-HT) into the central nervous system (CNS) may contribute to enhanced levels of central fatigue. Given that the release of 5-HT in the spinal cord is likely associated with the intensity of muscle contraction, 5-HT-related fatigue effects may differ with the intensity of contraction that leads to fatigue (Cotel et al., 2013; Kavanagh et al., 2019; Thorstensen et al., 2020). Thus, the purpose of this study was to investigate how enhanced 5-HT availability affects voluntary muscle activation during fatigue-inducing submaximal and maximal contraction tasks. In two experiments participants performed intermittent isometric elbow flexions that caused fatigue. For each experiment, they ingested a selective serotonin reuptake inhibitor (20 mg paroxetine) or a placebo on separate days. In the first experiment ($n = 11$), twelve 20% maximal voluntary contractions (MVC) of 2-min duration were performed, separated by 40-s rests. In the second experiment ($n = 14$), 12 MVCs of 10-s duration were performed separated by 40-s rests. In both experiments, measures of voluntary activation were calculated from superimposed twitches evoked by transcranial magnetic stimulation during brief contractions of MVC, 75% MVC and 50% MVC immediately after each sustained contraction. Peak MVC torque progressively declined to ~59% and ~48% of unfatigued baseline measures for experiment 1 and experiment 2 respectively. For the first experiment there was no main effect of drug ($p = 0.856$), and no drug by contraction interaction effect ($p = 0.073$), for voluntary activation. In contrast, a main effect of drug ($p = 0.018$) was detected for the maximal contraction protocol of the second experiment, where voluntary activation was significantly lower for the paroxetine condition

compared to the placebo condition. A drug by contraction interaction effect was also detected for the maximal contraction protocol (p = 0.002), where voluntary activation was significantly lower for the paroxetine condition compared to the placebo condition from the 8th contraction onwards (mean difference (%): 5.32 ± 0.45). The findings indicate that higher 5-HT availability leads to greater central fatigue after repeated maximal, but not submaximal (20% MVC), contractions. This confirms that 5-HT is a key contributor to central fatigue in humans and that high intensity contractions are compromised when 5-HT accumulates in the CNS. It is probable that strong descending drive to the target muscle is associated with high levels of release of 5-HT in the spinal cord, where an accumulation of 5-HT activates extrasynaptic inhibitory 5-HT1A receptors on motoneurons.

O3.2 Less common synaptic input between muscles from the same group allows for more flexible coordination strategies during a fatiguing task.

Julien ROSSATO[1], Kylie TUCKER[2], Simon AVRILLON[3], Lilian LACOURPAILLE[1], Ales HOLOBAR[4], François HUG[5]

[1]Université de Nantes, [2]The University of Queensland, [3]Shirley Ryan AbilityLab, [4]University of Maribor, [5]Université Côte d'Azur

BACKGROUND AND AIM: Redundancy of the neuromuscular system theoretically allows for a redistribution of the neural drive across muscles (i.e., compensation or differential changes). However, a high level of common input between muscles may represent a neural constraint making it less likely to redistribute the neural drive across these muscles. This study aimed to determine whether neural drive is redistributed between muscles during a fatiguing isometric contraction, and if so, whether the initial level of common synaptic input between these muscles constrains this redistribution. METHODS: We studied two muscle groups, which exhibit different level of common synaptic input: the triceps surae (14 participants) and the quadriceps (15 participants). Participants performed a series of submaximal isometric contractions and a torque-matched contraction maintained until task failure. We used high-density surface electromyography to identify the behavior of 1874 motor units from the soleus, gastrocnemius medialis (GM), gastrocnemius lateralis (GL), rectus femoris, vastus lateralis (VL), and vastus medialis (VM). We assessed the level of common drive between muscles in absence of fatigue using a coherence analysis. We also assessed the redistribution of neural drive between muscles during the fatiguing contraction through the correlation between their cumulative spike trains (index of neural drive). RESULTS: The level of common drive between VL and VM was significantly higher than that observed for the other muscle pairs, including GL-GM. The level of common drive increased during the fatiguing contraction, but the differences between muscle pairs persisted. We also observed a strong positive correlation of neural drive between VL and VM during the fatiguing contraction (r=0.82). This was not observed for the other muscle pairs, including GL-GM, which exhibited differential changes in neural drive. CONCLUSIONS: These results suggest that less common synaptic input between muscles allows for more flexible coordination strategies during a fatiguing task, i.e., differential changes in neural drive across muscles. The role of this flexibility on performance remains to be elucidated. The fact that the differences between muscle pairs persisted with fatigue provides evidence of the robustness of the common drive. It suggests that the common drive between muscles originate from structural connections, hardwired in anatomical circuits, such as premotor interneurons that project to multiple motor neuron pools.

O3.3 Identification of electromyographic indicators to assess the myoelectric manifestation of fatigue during a low-load repetitive pointing task.

ELVIGE FEGNI NDAM[1], Etienne Goubault[1], Béatrice Moyen-Sylvestre[1], Fabien Dal Maso[1]
[1]Université de Montreal

Introduction Industrial work such as assembling or manual handling involves repetitive movements, elevated arm postures, constrained workplaces, and long periods of sustained muscle activity that cause muscle fatigue, which is a risk factors for the development of musculoskeletal disorders. Of the existing methods for assessing muscle fatigue, measures based on electromyographic (EMG) are the most common because they best reflect the activity of the motor units. Linear indicators, such as median frequency and activation levels, are typically used to assess the myoelectric manifestation of fatigue (MMF). However, EMG shows complex behaviour so that a variety of complex indicators have recently been used to assess MMF. The aim of this study was to determine the best EMG indicators of the MMF. We hypothesize that compared to linear indicators complex indicators can detect additional EMG features that will improve the assessment of MMF. Methods Twenty-four healthy right-handed participants were recruited. Ten surface EMG electrodes were positioned on their anterior serratus; anterior, medial, and posterior deltoids; biceps brachii; lateral head of the triceps brachii; and upper, inferior, and posterior trapezius. Participants performed a fatiguing repetitive pointing task (RPT) with their dominant arm. They reported their rate of perceived exertion (mRPE) every 30 seconds using the modified CR-10 Borg scale and were stopped when they reached a score of 8 or higher. Median frequency, mobility, activity and activation level were calculated as linear indicators of MMF and chaos, entropy, correlation, fractals and self-similarity measures were calculated as complex indicators of MMF. A partial least square regression (PLSR) was performed to predict the evolution of the mRPE scores across the RPT from the 14 MMF indicators computed from the 10 muscles EMG signals making a total of 140 inputs (14*10). Results The PLSR model explained 72.71 ± 2.19% of the mRPE variance with an absolute error of 1.34 ± 0.31 on mRPE values. Mobility, median frequency, spectral entropy, fractal Higuchi, and fractal Hurst exponent were the MMF indicators that had the highest importance to predict mRPE scores. The posterior and medial deltoids, the biceps, the triceps and the median trapezius had the highest importance to predict mRPE scores. Conclusions The PLSR analysis highlighted that the two deltoid muscles, which are known to fatigue the most during RPT, are the ones that most explained the mRPE variance. This latter result confirms that PLSR analysis is reliable for predicting mRPE from EMG indicators. Median frequency, spectral entropy, fractal Higuchi and fractal Hurst exponent were the most suitable indicators to assess MMF. Alternatively, correlation dimension should no longer be considered for assessing MMF. This study shows for the first time that the combination of different types of indicators may help to better assess MMF, thus taking into account the limits related to the complex nature of sEMG. In turn, the combination of these different indicators could address issues related to the prevention and treatment of MSDs in workers.

O3.4 Trunk extensor muscle action potential conduction velocity estimated using high-density EMG

Niels Brouwer[1], Ali Tabasi[1], Idsart Kingma[1], Dick Stegeman[1], Wietse van Dijk[2], Alejandro Moya-Esteban[3], Massimo Sartori[3], Jaap van Dieën[1]
[1]Vrije Universiteit, [2]TNO, [3]University of Twente

BACKGROUND AND AIM: Tasks involving sustained trunk extensor muscle activity and low trunk extensor endurance have been associated with low back pain. Decreasing motor unit action potential conduction velocity (CV) is considered a direct measure of muscle fatigue development. However, estimating the trunk extensor CV from surface EMG has been proven difficult possibly due to the presence of non-travelling potentials resulting in low cross-correlation-based Pearson correlation (R) between signals from adjacent electrodes and too high CV values. For other muscles, a peak-delay method was used to estimate the CV between individual, strongly correlated (R>0.9) EMG peaks, while excluding non-travelling potentials. The aim of this study was to estimate the trunk extensor CV from high-density surface EMG (HD-sEMG) using (1) the peak-delay method (DelayCV); and (2) the cross-correlation method (CorrCV). Since in this context no gold-standard method can be considered, we considered the estimation valid when both CV estimates agreed. METHODS: Fourteen healthy male participants without a history of low back pain performed a 30 degrees lumbar flexion trial until exhaustion while standing. HD-sEMG was obtained at right side of the spine using an 8x8 electrode grid which covered the area between the L3 and T12 spinous process. Data from the first 300 seconds of the trial were included. Per pair of double differential channels (constructed in cranial-caudal direction), the median CV per 10s was estimated with each method. Per participant the agreement between the DelayCV and CorrCV was assessed using non-parametric Bland Altman statistics from sites (i.e., spatial representation of a pair of double differential channels) for which: (1) both estimates fell within the expected physiological range of CV (2-6 m/s); and (2) the average peak-delay-based peak density exceeded 40 peaks/10s. No cross-correlation-based R threshold was considered. RESULTS: In contrast to previous studies, propagating potentials were observed and in 10 out of 14 participants, for 118 (out of 560) sites, both the DelayCV and CorrCV met the two criteria. The spatial distribution of these sites indicated that we primarily estimated the CV of the iliocostalis lumborum muscle. The average CV corresponded well between methods (see figure). The R values of the CorrCV were mostly within the range 0.51-0.91. The Bland Altman analysis revealed small differences (median ΔCV: -0.12-0.23 m/s) and on average strong correlations (median R²: 0.79) between the DelayCV and CorrCV. CONCLUSIONS: Although the CorrCV R values were lower than typically accepted, the DelayCV and CorrCV showed close agreement and a considerable number of estimations fell within the expected physiological range. Contributions of motor units with a relatively larger amplitude and high CV may explain the slightly higher DelayCV compared to the CorrCV as found in most participants.

O3.5 Examining the influence of exertion/rest order effects on predicted muscle fatigue: a simulation study

Ryan Foley[1], Nicholas La Delfa[1]
[1]Ontario Tech University

<b>BACKGROUND AND AIM:<b> Several ergonomics approaches are currently available to help control muscle fatigue in the workplace, but these tools are typically limited to simple intermittent and isotonic force levels. Recent approaches have been developed to estimate workload thresholds for more 'complex' work involving contractions of different intensities and durations (e.g. RCRA by Gibson & Potvin, 2016). However, this approach does not consider the order in which the efforts and rest occur. The specific timing of rest periods between efforts (e.g. evenly distributing rest, or providing a longer rest period following consecutive efforts), and the sequencing of different contraction intensities (e.g. higher contraction followed by lower contraction levels) may allow for differential fatigue and recovery, but to what degree is currently unknown. The purpose of this study was to investigate how different patterns and sequences of exertions and rests, of otherwise equivalent workloads, can affect predicted fatigue outcomes. <b>METHODS:<b> A computational motor unit fatigue model (Potvin & Fuglevand, 2017) was used to quantify differences in fatigue between sixty variations of an intermittent force profile with equivalent average force and duty cycle (i.e. % of task time producing effort). Profiles were

divided into five 12-second segments, which combined to represent a 1-minute cycle. Each cycle consisted of three different exertion intensities (low = 4.5%MVC, med = 15%MVC, high = 27.5%MVC) and 2 rests (0%MVC). The force profiles were differentiated according to two variables: 6 'patterns' - the order of exertion level (e.g. 'high-low-medium') x 10 'sequences' - the distribution of exertions and rests (e.g. 'effort-rest-effort-rest-effort'). Remaining strength capacity of the motor unit pool following a 1-hour simulation (i.e. 60 repeating cycles), smoothed with a 1-cycle moving average, was the main indicator of fatigue. <b>RESULTS:<b> All profiles induced a mean decline of 2.0±0.1 %MVC. Those that induced the most and least fatigue were the 'high-med-low-rest-rest' sequence (-2.15 %MVC) and the 'med-rest-high-rest-low' sequence (-1.83 %MVC), respectively (Fig 1). 'High-med-low' was the most fatiguing contraction pattern (-2.11 ± 0.13 %MVC), likely due to a high force followed by no immediate rest. Interestingly, interspersed rests showed the ability to ameliorate the effects of a pattern with the highest force occurring early (e.g. 'high-med-low'). <b>CONCLUSIONS:<b> Despite equivalent average force intensity and exertion time, the order of exertion intensity and placement of rest breaks had a noticeable effect on fatigue accumulation. While the difference in fatigue between the most and least fatiguing conditions seems minimal over the course of this 1-hour simulation, further pilot simulations indicate this gap expands to substantial levels when tested over an 8-hour workday. These results can inform work task resequencing to minimize muscle fatigue development.

O3.6 Peak rate of velocity development of electrically evoked contractions is impaired less than voluntary contractions in the plantar flexors following a dynamic fatiguing task

Michael Paris[1], Charles Rice[1]
[1]*University of Western Ontario*

BACKGROUND AND AIM: Peak power during dynamic contractions is a fundamental determinant of skeletal muscle function. A high rate of velocity development (RVD, i.e., acceleration) is critical for achieving maximal power, which may be influenced by the rate of neural activation. During fatiguing tasks, peak RVD may be impaired more than peak power, but few studies have evaluated these time-dependent contractile features. Fatigue-related reductions in RVD may occur due to impairments in central or peripheral (or both) aspects of the neuromuscular system, which can be assessed partly by comparing changes in voluntary and electrically evoked dynamic contractions following a fatiguing task. Our objective was to characterize voluntary and electrically evoked peak RVD following a dynamic voluntary fatiguing task and throughout short-term recovery (10 minutes). We hypothesized that peak RVD of electrically evoked contractions will be reduced less than voluntary, but both will recover in a similar timeframe. METHODS: Young adults (18-35 years, n=5) performed concentric, maximal isotonic-like plantar flexion contractions (Humac Norm) at a resistance of 20% maximal voluntary contraction (MVC) through a 25° ankle joint range of motion (80° to 105° plantar flexion) until a 75% reduction in peak power (task failure). Bipolar surface electromyography (sEMG) was recorded from the medial gastrocnemius and soleus. Electrically evoked isotonic-like contractions were stimulated at 300 Hz (tibial nerve in the popliteal fossa). The current which elicited maximal tetanic isometric torque was used for evoked dynamic contractions. Evoked isotonic-like contractions were performed at a resistance of 20% maximal tetanic force. Peak RVD of voluntary and evoked dynamic contractions and rate of sEMG activation (0 to 75 ms after onset) of voluntary dynamic contractions were evaluated at baseline, immediately, 2.5-, 5-, and 10-minutes post task failure. RESULTS: Participants completed (mean ±SD) 126 ±72 contractions. Evoked tetanic (300 Hz) torque achieved ~78% of voluntary MVC. Following task failure, voluntary RVD was reduced ~42%, which remained depressed at 10 minutes of recovery (~25%

reduced). Impaired voluntary RVD coincided with reduced rate of sEMG activation following task failure (~44% reduced), which remained depressed at 10 minutes of recovery (~33% reduced). Electrically evoked RVD was reduced ~24% at 0.5 minutes post task failure but recovered to baseline by 2.5 minutes (~2% reduced). CONCLUSIONS: In these 5 participants to date, following a dynamic fatiguing task, peak voluntary RVD was impaired to a greater extent and took longer to recover compared with electrically evoked RVD, which may be due to reduced rate of neural activation. Impairments within the central nervous system may be present following a dynamic fatiguing task and throughout acute recovery, contributing to reduced generation of skeletal muscle power.

O3.7 Modulation of intermuscular beta coherence for mental fatigue during treadmill walking is similar in younger and older

Paulo Cezar Santos[1], Fabio Barbieri[2], Claudine Lamoth[3], Tibor Hortobágyi[3]
[1]Weizmann Institute of Science, [2]São Paulo State University, [3]University Medical Center Groningen, University of Groningen

Introduction: Age-related declines involve reduced cognitive functions that are related to poor gait performance. Reasonably, this condition may reflect the older adults' capacity to adapt their gait to mental fatigue, defined as a decline in cognitive performance after continuous exposure to demanding mental tasks. Previous evidence indicated that mental fatigue increased stride outcomes variability during a dual task walking in older but not in younger adults. During a single task walking, both younger and older had stride outcomes relatively maintained, but both groups may still have resources to cope with induced mental fatigue by modulating cortico-muscular communication, measured by intermuscular beta coherence. Intermuscular beta coherence indicates a coupling in the oscillatory drive via corticospinal tracts. We examined the age and mental fatigue effects on intermuscular coherence during treadmill walking. Methods: Older (n=12) and Younger (n=12) walked on a treadmill at 1.2m/s before and after experimentally induced mental fatigue by randomly performing 30 minutes of 3 computer tasks (Psychological Vigilant Test (PVT), Stroop test, and AX-Continuous Performance Task). During treadmill walking, means and coefficient of variations (CV) for stride length, width and duration, and stance and swing time were calculated considering 100 consecutive heel strikes of the preferred leg. On the same strides, we measured the electromyographic activity of Vastus lateralis (VL), Rectus femoris (RF), Biceps femoris (BF), Semitendinosus (ST), Tibial Anterior (TA), Peroneus longus (PL), Gastrocnemius (GM), Soleus (SL) during the swing and stance phases. We computed coherence for late swing (-400 to -50ms) and early stance (50 to 400ms), considering the squared modulus of the cross-spectrum normalized by the product of auto-spectra. We calculated the amount of coherence as the cumulative sum for beta frequency band (15-35Hz) for the synergistic (RF-VL, BF-ST, TA-PL, and GM-SL) and antagonistic (RF-BF and TA-GM) muscle pairs. We applied ANOVA with between factor age groups and within factor mental fatigue to examine the effect of group and mental fatigue on mental tasks performance, coherence, and stride outcomes. Results: At the end of the mental task, both age groups performed the PVT and Stroop tasks slower (7-15%, $p<0.05$). Age main effect indicated that older vs. younger adults had 6% lower mean, and 24% higher CV of swing time ($p<0.05$), and had ~57% lower GL-SL and TA-PL coherence during the swing and stance phases (both $p<0.001$). Mental fatigue main effect indicated that both groups increased the CV of stride length and swing (16-18%), the beta coherence between BF-ST, GL-SL, and TA-PL during swing (24-56%), and the beta coherence between RF-VL and BF-ST during stance (32-98%, all $p<0.05$). Conclusion: Although age-differences in intermuscular coherence, both younger and older adults increased beta coherence between synergistic muscle pairs to cope with

the mental fatigue effects on swing time and to relatively maintain the other behavioral gait outcomes unchanged.

Oral 4 – Motor Disorders

O4.1 Cortical activation of lower extremity recovery during inpatient stroke rehabilitation

Sue Peters[1], Chieh-ling Yang[2], Shannon Lim[3], Janice Eng[3]
[1]Western University, [2]Chang Gung University, [3]University of British Columbia

BACKGROUND: Considering stroke damages the brain, little data shows how stroke rehabilitation may change brain activation. An in-depth look the brain's response to inpatient therapy may shed light on how rehabilitation impacts brain activation. Using functional near-infrared spectroscopy (fNIRS), prefrontal cortex changes are shown in stroke; however, no one has examined changes in sensorimotor regions. Measuring brain activation weekly during rehabilitation may provide insight into mechanisms of sensorimotor recovery. Thus, the aim is to explore brain activation in sensorimotor regions across rehabilitation and relate to clinical outcomes. METHODS: Subacute stroke patients were recruited from an inpatient stroke unit (GF Strong Rehab Centre). The NIH Stroke Scale was assessed at baseline to measure stroke severity. Clinical outcomes included the Fugl-Meyer Lower Extremity (FM-LE), and Short Performance Physical Battery (SPPB) completed by a licensed physical therapist. fNIRS assessments took place weekly and participants performed: 1) active, and 2) passive paretic knee flexion/extension. Instructions were to maintain timing at 0.5Hz, and 1) to actively extend the knee, and 2) to relax and passively allow the researcher to move the knee. A fNIRS system (NIRSport2) assessed brain activation with 16 sources and 15 detectors, with 8 short separation channels. Using HomER2, raw intensity data were converted to optical density, then to concentration changes of oxy- and deoxy-hemoglobin. Last, the hemodynamic response function was estimated, with regression of short separation channels to remove extracerebral signals. A general linear model was employed, with the output visually inspected, comparing changes within participants across each week of inpatient stroke rehabilitation. RESULTS: 2 individuals with stroke (Hemiparesis: 1 left, 1 right; NIHSS: 5 and 6) participated in this case series (4, 6 weekly assessments). Participants improved scores on clinical measures (FM-LE: S1 12 to 21/34, S2 4 to15/34; SPPB: S1 0 to 5/12, S2 0 to 5/12). The hemodynamic response showed larger activation early (compared with late in rehab) across both hemispheres in sensorimotor regions for passive knee movement. Active knee movement showed the inverse, with small levels of activation near baseline which increased during inpatient rehabilitation. As clinical scores improved, activation increased with active movement and decreased with passive movement. CONCLUSIONS: Brain activation decreased with passive and increased with active lower extremity movement. A relationship may be present in brain activation changes and clinical measures. If passive movement generates larger brain activation early in rehabilitation, therapies where patients are passively moved, like robotics, may warrant further emphasis as a therapy type, with the transition to greater active movement as recovery is observed. A future clinical trial may be justified to explore these relationships further.

O4.2 Short term effects of modulating the excitability of the posterior parietal cortex with rTMS for freezing of gait in Parkison's disease

Alexandra Potvin-Desrochers[1], Alejandra Martinez Moreno[1], Julien Clouette[1], Henri Lajeunesse[1], Freddie Seo[1], Gleydciane Alexandra Fernandes[1], Frédérike Parent-L'Ecuyer[1], Audrey Parent[1], Michelle Cheng[1], Madeleine Sharp[1], Caroline Paquette[1]
[1]McGill University

BACKGROUND & AIM Freezing of gait (FOG) is a common motor symptom of Parkinson's disease. It is described as a brief and sudden inability to take a step despite the intention to walk. The posterior parietal cortex (PPC), a key brain area for visuospatial processing and locomotion, has been repetitively shown to be involved in the neural correlates of FOG. However, current neuroimaging modalities does not allow to precisely determine the role of the PPC in real FOG episodes. Thus, the purpose of this study was to modulate PPC cortical excitability using repetitive transcranial magnetic stimulation (rTMS) to determine whether PPC activity contributes to FOG or compensates for dysfunctional neural networks to avoid FOG. METHODS Fifteen individuals with Parkinson's disease and FOG were recruited. Participants took part into 4 sessions, separated by at least 72 hours, while being in their ON-medication state. The initial session consisted of a clinical assessment, which was followed by TMS protocols to determine the appropriate areas to stimulate (hotspots) and the motor thresholds. There were three randomized experimental sessions: inhibitory rTMS on the PPC, excitatory rTMS on the PPC and a sham rTMS. The experimental measurements were acquired and compared before and after each stimulation protocol. FOG severity outcomes (FOG-provoking test score, percent time frozen, time to complete the FOG-provoking test, time to turn, number of steps to turn), gait kinematics, cortical excitability measurements of the PPC and of the tibialis anterior motor cortex, UPDRSIII and the performance on the trail making test were analyzed. RESULTS Preliminary data is presented for 8 participants. The percent time frozen and the mean number of steps to turn (mean change: -3% ± 8%, P=0.08 and mean change: -6 steps ± 3 P=0.09, respectively) tended to be reduced after increasing PPC excitability compared to the two other protocols. Increasing and decreasing PPC excitability significantly decreased the UPDRSIII score (cTBS: -3 ±3, P=0.0091 and iTBS: -4 ± 3, P=0.0294, while the sham protocol had no effect on it. The time to complete the trail making test Part A tended to be reduced after decreasing PPC excitability (P=0.058), but the change in performance was not significantly different from the other protocols. Finally, none of the protocols induced changes in the tibialis anterior motor cortex excitability, nor in the functional connection between the PPC and the leg motor cortex. CONCLUSION Preliminary data tend to show that less time spent in FOG, more efficient turning and less severe Parkinson's motor symptoms are linked to an increased excitability of the PPC. This could suggest that facilitating the recruitment of the PPC with rTMS could enhance visuospatial processing and act as a compensatory mechanism for less FOG and more efficient walking in PD.

O4.3 Fasciculation electromechanical latency is prolonged in amyotrophic lateral sclerosis

James Bashford[1], Domen Planinc[1], Cristina Cabassi[1], Nazifa Muhamood[1], Emma Hodson-Tole[2], Christopher Shaw[1]
[1]King's College London, [2]Manchester Metropolitan University

BACKGROUND AND AIM: In amyotrophic lateral sclerosis (ALS), motor neurons become hyperexcitable and spontaneously discharge electrical impulses called fasciculations. They can be detected by two non-invasive methods, namely high-density surface electromyography (HDSEMG) and muscle ultrasonography (MUS). We combined these two methods simultaneously to explore the electromechanical properties of fasciculations, seeking a novel biomarker of disease. METHODS: Twelve ALS patients and thirteen healthy participants each provided up to 24 minutes of recordings from the right biceps brachii (BB) and gastrocnemius medialis (GM). Two automated algorithms (the Surface Potential Quantification Engine and a Gaussian mixture model) were applied to HDSEMG and MUS data to identify fasciculations. We defined correlated fasciculations as those that produced an electrical peak on HDSEMG followed by a mechanical peak on MUS within 500 milliseconds. A linear mixed-effect regression model was employed to account for pseudoreplication within the dataset. RESULTS: A total of 4,197 correlated fasciculations were identified (2,520 in ALS-GM; 1,489 in ALS-BB; 185 in Healthy-GM; 3 in Healthy-BB). HDSEMG reliably detected fasciculations up to 30mm below the skin surface with an inverse correlation between amplitude and depth in ALS muscles. Electromechanical latency was prolonged in ALS-GM (mean=108.8ms; p=0.0458) and ALS-BB (mean=112.0ms; p=0.0128) compared to Healthy-GM (mean=79.8ms). However, electromechanical latency in ALS patients did not correlate with disease duration, symptom burden, muscle strength or fasciculation frequency. CONCLUSIONS: We successfully demonstrated the practical feasibility of simultaneous HDSEMG and MUS. Correlated fasciculations were reliably identified as deep as 30mm from the skin surface, highlighting the spatial sensitivity of HDSEMG. Most significantly, the prolonged electromechanical latency observed in ALS patients indicates impairment of the intramuscular excitation-contraction coupling mechanism, which not only provides pathophysiological insight but warrants further exploration as a potential novel biomarker of disease.

O4.4 Proximal spinal stretch reflexes are not affected in individuals treated with neurotoxic chemotherapy

Allison Wang[1], Stephen Housley[2], Ann Flores[1], Timothy Cope[2], Eric Perreault[1]
[1]Northwestern University, [2]Georgia Institute of Technology

BACKGROUND: Oxaliplatin (OX) chemotherapy can lead to long-term sensorimotor impairments in cancer survivors. The impairments are often thought to be caused by OX-induced progressive degeneration of sensory afferents from the distal to proximal direction, a phenomenon commonly known as dying-back sensory neuropathy. However, recent preclinical work has identified encoding dysfunction of muscle proprioceptors as an alternative mechanism. Muscle proprioceptors play an essential role in stretch reflexes. Encoding dysfunction could readily lead to deficits in reflexes, affecting motor control, including the ability to respond to unexpected perturbation and maintain limb stability. Furthermore, the deficits might be extensive and may occur even in the proximal region of the limbs, where dying-back sensory neuropathies are not commonly reported. This study aims to evaluate the integrity of the reflex responses in the proximal joints of cancer survivors to determine if they might be used as a biomarker for chemotherapy-induced proprioceptive dysfunction. We hypothesized that cancer survivors would exhibit impaired proximal stretch reflexes. METHODS: We evaluated stretch reflexes in the shoulder muscles of 16 cancer survivors treated with OX (51±11 years) and 16 healthy controls (51±12 years). Subjects were seated with their dominant arm attached to a rotary motor at 90° shoulder abduction and 20° horizontal adduction and their trunk secured. The rotary motor delivered small, rapid, stochastic perturbations to elicit stretch reflexes while subjects maintained a steady shoulder horizontal adduction and abduction torque (5%, 10% maximum voluntary contraction). Surface electrodes recorded activity in the pectoralis major, anterior and posterior deltoids, triceps, and biceps muscles. We quantified the background activity and the short latency reflex in the -40 - 0 ms and 20 - 50 ms window relative to perturbation onset, respectively. Sensory neuropathy was assessed using conduction studies on the median, ulnar, and radial nerves. RESULTS: The amplitude of the short latency reflexes increased with increased background muscle activity in all muscles ($p<0.01$), but we found no significant differences in the slopes ($p>0.21$) or intercepts ($p>0.11$) of this relationship between the two participant groups. This negative finding was present even though the cancer survivors exhibited decreased nerve conduction amplitude and velocity in the median, ulnar, and radial nerve compared to controls, indicating distal sensory neuropathy. CONCLUSIONS: The distal sensory neuropathies detected

in the cancer survivors were consistent with those reported in the literature. However, we did not find significant proximal stretch reflexes deficits using our experimental protocol, even though we previously reported proximal deficits in functional tasks requiring proprioception in a similar subject population. It remains to be determined if our negative finding is due to the many differences between our human protocols and the earlier preclinical studies assessing stretch reflexes or if chemotherapy did not lead to stretch reflex dysfunction in our subject group.

O4.5 People with Multiple Sclerosis show evidence of reduced motor cortical voluntary activation during sustained maximal contractions

Emily Brotherton[1], Surendran Sabapathy[1], Justin Kavanagh[1]
[1]Menzies Health Institute Queensland

BACKGROUND AND AIM: People with multiple sclerosis (PwMS) frequently report excessive levels of fatigue that interfere with daily living. Reports of heightened muscle fatigability during exercise have been linked to impairments in neural activation of the muscle. Although it is likely that the output of the motor cortex is compromised in PwMS during exercise, there is little empirical evidence to support this viewpoint. Therefore, the purpose of this study was to use transcranial magnetic stimulation (TMS) to assess fatigue-related levels of motor cortical voluntary activation (VA) across a full range of forces in a cohort of MS patients. METHODS: Five MS (42 ± 4 yr) and five controls (36 ± 4 yr) performed sustained maximal elbow flexions until force declined to 60% of unfatigued maximal voluntary contraction (MVC). Immediately following each fatigue-inducing contraction, target elbow flexion forces of 25%, 50%, 75%, 90 %, and 100% MVC were performed in random order. Single-pulse TMS (Magstim 2002) was delivered to the primary motor cortex with a circular coil during each target force to elicit superimposed twitches in elbow flexors. Estimates of resting twitch were calculated from linear regression of the superimposed twitch amplitude at 50%, 75%, and 100% MVC target forces. The amplitude of evoked responses was normalised to responses for a single electrical stimulus delivered to the brachial plexus (DSAH7, Digitimer). VA was calculated as (1-superimposed twitch/resting twitch) x 100. RESULTS: All MS and controls were able to complete the fatigue tasks and target elbow flexion forces in this study. There was a main effect of group for motor cortical VA ($p = 0.003$), where post-fatigue VA was reduced to a greater extent in the MS group compared to controls across the full ranges of forces. Fatigue-related changes in VA were accompanied by greater increases in motor cortical superimposed twitches, and greater reductions in RMS EMG of the biceps brachii, in the MS group compared to controls. CONCLUSIONS: Between-group differences in TMS-evoked VA suggest that PwMS had suboptimal output of the motor cortex following fatigue-inducing contractions. This decline in VA was apparent across a full range of target forces and was not specific to a particular post-fatigue contraction intensity. Therefore, it appears that the neural impairments caused by MS lead to widespread deficits in motor activity during tasks that induce considerable levels of fatigue. Data collection for this project is ongoing.

O4.6 Variability of Neural/Musculoskeletally-modelled Ankle Joint Torques during Gait in Children with Cerebral Palsy

Shui Kan Lam[1], Harri Piitulainen[2], Juha-Pekka Kulmala[3], Ivan Vujaklija[1]
[1]Aalto University, [2]University of Jyväskylä, [3]University of Helsinki and Helsinki University Hospital

BACKGROUND AND AIM: Robot-aided therapies are an emerging technique supporting the rehabilitation of Cerebral Palsy (CP) children. Preferably, partial assistance robots operating around humans are torque-controlled [1]. In absence of unobstructive direct measurements, human joint torques are estimated via different modelling approaches. The Electromyography (EMG)-driven musculoskeletal modelling [2] considers neural aspects in addition to kinematics as compared to traditional inverse dynamics (ID). Understanding of CP joint torque properties modelled either way is still limited. This study aims to investigate the variability of ankle joint torques within different CP subtypes, including hemiplegia with GMFCS I (HP1) and diplegia with GMFCS I (DP1) and II (DP2), and their similarities to typically developed (TD) control subjects during gait, using the two modelling approaches. METHODS: We investigated three subjects from each of the four study groups during ground-level walking at self-selected speeds (Helsinki University Hospital ethics HUS/2318/2016). Marker trajectories and ground reaction forces were acquired using 8-camera motion capture system (Vicon, Oxford, UK) and force plates (AMTI, MA). EMG signals of three muscles, namely, tibialis anterior, peroneus longus, medial gastrocnemius, were recorded from right leg for diplegia and TD and the affected leg for hemiplegia volunteers using a wireless system (Myon, Switzerland). Subject-specific ankle joint torques were computed via i) ID and ii) EMG-driven musculoskeletal modelling [2]. We then analysed the extent in which individual torques correlate to their own group means (intra-group correlation) and to the TD mean (inter-group correlation). RESULTS: Intra-group variability inferred from correlation coefficients (Figure A) descended in the following orders for ID and for EMG-driven model, respectively: TD (Σ r = 2.99), DP1 (Σ r = 2.84), HP1 (Σ r = 2.75), DP2 (Σ r = 2.74); TD (Σ r = 2.96), HP1 (Σ r = 2.66), DP1 (Σ r = 2.65), DP2 (Σ r = 2.45). The difference between GMFCS I and II resulted from EMG-driven model (Δr = 0.21) was larger than that from ID (Δr = 0.055). The difference within the GMFCS I resulted from the EMG-driven model (Δr = 0.01) was smaller than that from ID (Δr = 0.09). For inter-group comparison (Figure B), the trends induced by both models were the same. That is, as compared to the TD mean, DP2 deviated the most (Σ r = 1.87/1.07), followed by HP1(Σ r = 2.10/2.01), then DP1(Σ r = 2.64/2.50). The difference between GMFCS I and II obtained from EMG-driven model (Δr = 1.19) was larger than that from ID (Δr = 0.50), and the difference within groups of GMFCS I from EMG-driven model (Δr = 0.49) was smaller than that from ID (Δr = 0.54). CONCLUSIONS: DP2 showed the highest intra-group variability and was the least correlated to the TD mean in both neural/musculoskeletal cases. The torques estimated from EMG-driven model of this type appeared more interpretable according to motor function severity. REFERENCES: [1] Baud et al. J NeuroEng Rehab. 2014; [2] Sartori et al. PLoS ONE. 2012

Oral 5 – Clinical Neurophysiology

O5.1 New analytical models to investigate sensory re-weighting mechanisms using vibration-induced postural reactions paradigm

Mohamed A. Kadri[1], Emilie Bouchard[1], Lydiane Lauzier[1], Hakim Mecheri[2], William Begin[1], Martin Lavallière[1], Hugo Massé-Alarie[3], Rubens A. da Silva[1], Louis-David Beaulieu[1]

[1]Université du Québec à Chicoutimi, [2]Institut de recherche Robert-Sauvé en santé et en sécurité de travail, [3]Université Laval

Vibration of tendons (VIB) during postural control represent a common tool to generate postural reactions (PR). Recently, a precise temporal analysis revealed that VIB-PR dynamically evolves over time, but no published procedure exists to quantitatively measure and discriminate between different VIB-PR patterns. The present study therefore proposes new graphical- and variability-based analytical models of VIB-PR patterns. Twenty young volunteers realized three experimental conditions of bipodal postural control (eyes closed) on a force platform: (i) Baseline without VIB; (ii) bilateral VIB of the tibialis anterior

(TA) and (iii) of Achilles tendons (ACH-T) at 80 Hz. Center of pressure (COP) analyses consisted of conventional stabilometric measures (antero-posterior (AP) Amplitude, Velocity) and the new variables calculated from mean COP AP position at 0.5 s time-points: area under the curve, linear slope, total displacement, standard deviation (SD) of COP position and SD of distances between 0.5s time-points. Conversely to conventional measures, the new variables found significant differences between different phases of VIB-PR, between TIB and ACH conditions, and highlighted different patterns of VIB-PR. The proposed analyses could have a great scientific impact by fostering new discoveries in the field of sensory re-weighting on postural control assessment/intervention in rehabilitation.

O5.2 Antagonism of the 5-HT2 receptor reduces human motoneuron excitability measured with F-waves but not cervicomedullary motor evoked potentials

Jacob Thorstensen[1], Janet Taylor[2], Justin Kavanagh[1]
[1]Griffith University, [2]Edith Cowan University

BACKGROUND AND AIM: To voluntarily activate muscle, descending motor pathways must activate motoneurons in the ventral horn of the spinal cord. If motoneurons are more excitable, more force is produced by muscle for the same excitatory input. Motoneuron excitability can be altered by neuromodulators such as serotonin (5-HT), and animal experiments and in vitro studies indicate that 5-HT increases motoneuron excitability by activating 5-HT2 receptors. However, it is not known if/how this receptor affects the output of human motoneurons in vivo. In the current study, we studied the effects of 5-HT2 receptor antagonism on human motoneuron excitability. METHODS: A single oral dose (8 mg) of the 5-HT2 antagonist cyproheptadine was administered to ten healthy participants in a double-blind, placebo-controlled, crossover trial. Before and after pill administration, two well-established electrical stimulation techniques were used to assess the excitability of motoneurons projecting to resting muscle. Specifically, cervicomedullary stimulation was used to evoke cervicomedullary motor evoked potentials (CMEPs) in the surface electromyography (EMG) signal of the biceps brachii. In addition, supramaximal ulnar nerve stimulation was used to generate F-waves in the abductor digiti minimi (ADM). We also assessed drug effects on biceps CMEPs after a brief contraction of the contralateral elbow flexors, and on elbow flexion isometric maximal voluntary contraction (MVC) performance. RESULTS: Compared to placebo, we found that 5-HT2 antagonism reduced the amplitude (placebo: 96.4 ± 13% of pre-pill amplitude, cyproheptadine: 66.3 ± 23.6%, P = 0.002) and persistence (placebo: -1.1 ± 4.7% difference in persistence from pre-pill, cyproheptadine: -9.4 ± 14.9%, P = 0.013) of F-waves in the ADM. Conversely, 5-HT2 antagonism did not affect the amplitude of biceps CMEPs, and there was no effect of drug on biceps CMEPs that were obtained after contraction of the contralateral elbow flexors. However, maximal voluntary force during brief elbow flexions (placebo: 303.6 ± 88.5 N, cyproheptadine: 284.6 ± 74.5 N) was reduced (P = 0.016). CONCLUSIONS: The reduction of F-waves with 5-HT2 antagonism suggests that 5-HT2 receptors modulate the intrinsic properties of human motoneurons to promote excitability. Conversely, as 5-HT2 antagonism did not affect CMEP amplitude, but reduced MVC force, we suggest that the effects of 5-HT on motoneuron excitability are only functionally relevant during repetitive motoneuron firing when persistent inward currents are activated. These results further our understanding about how neuromodulators control the excitability of human motoneurons and indicate that 5-HT is an important neurotransmitter for voluntary muscle activation.

O5.3 Vibration-induced modulation of central nervous system excitability of the flexor carpi radialis muscle

Clara PFENNINGER[1], Nathan GROSBOILLOT[2], Enrico ROMA[1], Guillaume DIGONET[1], Thomas LAPOLE[1]

[1]Inter-university Laboratory of Human Movement Biology, University of Lyon, UJM Saint-Etienne, EA 742, [2]HAVAE, EA6310, Faculty of Science and Technology, University of Limoges, 87000 Limoges, France

BACKGROUND AND AIM: Prolonged local vibration (LV) induces both acute and chronic neural adaptations 1. Immediately after LV exposure, spinal excitability is altered, as shown by an H-reflex depression 1. While this was initially thought to be due to presynaptic mechanisms, recent findings suggest an alteration in motoneuron excitability, as shown by the decrease in responses to corticospinal tract electrical stimulation in the lower limbs 2,3. Because at the same time, motor evoked potentials (MEPs) induced by transcranial magnetic stimulation (TMS) were reported to be unchanged, an increase in cortical excitability has been suggested to occur after prolonged LV to the quadriceps 3. Knowing that corticospinal excitability is differently modulated during LV to the lower vs upper limb muscles 1, this study aimed at determining the acute after-effects of 30-min LV of the flexor carpi radialis muscle (FCR) on spinal, motoneuronal, corticospinal and cortical excitability. METHODS: Nineteen healthy participants were engaged in this experiment for two sessions: a control condition and a LV session. Before, immediately after (POST), and 30 min after (POST30) each condition, responses to TMS (i.e. MEPs), corticospinal tract electrical stimulation (i.e. cervicomedullary evoked potentials; CMEPs) and nerve stimulation (i.e. H-reflexes) were recorded during a low-intensity contraction corresponding to 20% of maximal voluntary contraction. The hypothesis of equality of distribution was tested via Friedman test. Wilcoxon test was used for pairwise comparisons, applying Bonferroni correction. Results are presented as median [min - max]. RESULTS & DISCUSSION: No changes were observed in the control condition. At POST, CMEP decreased by 38 % [-80% - +68%] ($p = .0006$), suggesting a vibration-induced depression of motoneuron excitability. This depression was no longer observed at POST30 ($p = .7$). Similarly, the H-reflex decreased by 62 % [-84% - +55%] ($p = .0002$) after LV. This depression could be influenced not only by motoneuron excitability, but also by presynaptic mechanisms, being likely involved in the spinal loop depression still observed at POST30 ($p=.03$). No effect of vibration nor time was observed for MEP amplitude ($p = .5$) but the MEP/CMEP ratio increased by 57% [-48% - +396%] at POST ($p = .01$). This suggests a priming of cortical excitability after prolonged exposure to LV. Yet, values returned to baseline at POST30. CONCLUSION: Prolonged LV on the upper limb may lead to modulation of spinal, motoneuronal and cortical excitability as observed for the lower limbs. Priming of cortical excitability may be of interest to patients to promote brain plasticity. REFERENCES : 1. Souron, R. et al. Eur. J. Appl. Physiol. 117, 1939-1964 (2017). 2. Souron, R et al. J. Physiol. 597, 5179-5193 (2019). 3. Souron, R. et al. Front. Hum. Neurosci. 11, 519 (2017).

O5.4 Altered surface electromyographic activation in breast cancer survivors during functional arm movements

Pascal Madeleine[1], Gorm H Rasmussen[1], Afshin Samani[1], Mathias Kristiansen[1]
[1]Aalborg University

Altered surface electromyographic activation in breast cancer survivors during functional arm movements P. Madeleine, G. H. F. Rasmussen, A. Samani, M. Kristiansen. Sport Sciences - Performance and Technology, Department of Health Science and Technology, Aalborg University, 9220 Aalborg, Denmark. INTRODUCTION: Breast cancer survivors often report persistent pain around the shoulder, affecting motor function of the shoulder girdle (1). Thus, investigating the surface electromyography (SEMG) activation pattern of ventral and dorsal shoulder muscles can contribute to a better understanding of shoulder dysfunctions in breast cancer survivors. In this case-control study, we investigated the level of SEMG activation during isometric and dynamic arm abduction. METHODS:

Eleven women that had survived breast cancer and 11 matched controls volunteered to participate. The functional shoulder movements consisted of bilateral (i) static arm abduction at 90^o for 30-s and (ii) dynamic arm abduction (0-90^o) composed of three type of contractions: 2-s concentric, 2-s isometric and 2-s eccentric contractions repeated five times. The SEMG of pectoralis major (PM), deltoideus anterior (DA), deltoideus medialis (DM), upper trapezius (UT), middle trapezius (MT) and latissimus dorsi (LD) were collected on the affected side/matched side. Root mean square (RMS) values were computed over 0.5-s non-overlapping epochs during both the static and dynamic arm abduction and normalized to a reference contraction (5-s bilateral arm abduction at 90^o). RESULTS: For the static contraction, there was a main effect of group (patients/controls) showing that the normalized RMS values were significantly higher for the patients compared with controls (F=12.840, P<0.001). There were also a significant group x muscle interaction (F=3.373, P=0.005). The post-hoc analysis revealed that the normalized RMS values of DA and UT were significantly higher for the patients compared with controls (P<0.005). For the dynamic contraction, there were also main effects of group showing that the normalized RMS values were significantly higher for the patients compared with controls (F=9.105, P=0.003) and contraction type revealing higher RMS normalized values during concentric and isometric contraction compared with eccentric contraction (F=23.255, P<0.001). There were also group x muscle interaction (F=3.1893, P<0.001). The post-hoc analysis showed that the overall normalized RMS values of PM, DM and UT were significantly higher for the patients compared with controls (P<0.005). CONCLUSION: The present findings revealed higher relative level of activations during both static and dynamic contractions in breast cancer survivors with persistent pain compared with matched controls. These results confirm the presence of altered activation strategies in breast cancer survivors (2,3). (1) Andersen KG et al., J Pain, 2011. (2) Brookham RL and Dickerson CR, J Electromyograph Kinesiol, 2016. (3) Galiano-Castillo N et al., Am J Phys Med Rehabil, 2011.

O5.5 Effect of sex hormones on non-nociceptive flexion reflex at rest

Subaryani Soedirdjo[1], Yu-Chen Chung[2], Luis Rodriguez II[2], Hyungtaek Kim[2], Conner Hutcherson[2], Kathleen McGovern[2], Yasin Dhaher[2]

[1]UT Southwestern Medical Center, [2]University of Texas Southwestern Medical Center

BACKGROUND AND AIM. The rates of anterior cruciate ligament (ACL) injury are substantially higher in females compare to males (Slauterbeck et al., 2002). This injury may be caused by alteration of biphasic hamstring reflex which is mediated by polysynaptic pathway (Melnyk and Gollhofer, 2007). As Estradiol (E2) and progesterone (P4) receptors are present in the central nervous system, higher ACL injuries during follicular phase might be due to changes in hormone concentrations that affect the reflex pathway. In this study non-nociceptive flexion reflex (FR; the RII component) paradigm is used to investigate possible effect of changes in E and P on polysynaptic pathway. We hypothesize that RII component characterized at rest will be affected by fluctuating hormone levels during the menstrual cycle of young healthy women. METHODS. Seventeen healthy women ages 22-37 were tested every other day for one menstrual cycle. Serum E2 and P4 levels were measured. At least 10 trains of 200 Hz pulses were delivered to the distal tibial nerve at the lowest intensity that elicited stable RII response. A bipolar surface EMG (diameter = 1 cm) was placed on tibialis anterior according to SENIAM recommendation (sampled at 2 kHz, bandpass filter 20-500 Hz). Sessions were selected from each subject's data set to evaluate: A) the effect of E2, using two sessions of similar P4 levels but different E2 levels; B) the effect of P4, using two sessions of similar E2 levels but different P4 levels. Wilcoxon matched pairs signed rank test was used to compare the latency and RMS amplitude normalized to the

stimulus intensity of the responses. RESULTS. There were 14 pairs of sessions with matched hormone levels for each evaluation. A) Effect of E2 (Fig. 1A). The E2 levels of the two sessions (early follicular/EF and peri-ovulatory/O phases) are 37.3±15.5 pg/mL and 255.6±101.2 pg/mL with P4 levels of 0.37±0.2 ng/mL and 0.39±0.2 ng/mL respectively. The latency and normalized RMS amplitudes of the two phases are not significantly different (p>0.05). B) Effect of P4 (Fig. 1B). The P4 levels of the two sessions (peri-ovulatory and mid-luteal/L phases) are 0.49±0.28 ng/mL and 13.5±6.05 ng/mL with corresponding E2 levels of 185.2±77.89 pg/mL and 180.3±80.4 pg/mL. All the parameters of RII component are not significantly different between the two phases (p>0.05). CONCLUSIONS. The RII response is mediated by low threshold mechano-afferents through the A-beta fiber afferents. Our pilot data indicate that the changes in sex hormone concentrations do not modulate polysynaptic reflex parameters. This finding suggests that, spinal circuits in quiescent state is not affected by acute change in E2 or P4 levels.
REFERENCES. Melnyk, M., Gollhofer, A., 2007. Submaximal fatigue of the hamstrings impairs specific reflex components and knee stability. Knee Surgery, Sport. Traumatol. Arthrosc. 15, 525-532. Slauterbeck, J.R., Fuzie, S.F., Smith, M.P., Clark, R.J., Xu, K., Starch, D.W., Hardy, D.M., 2002. The Menstrual Cycle, Sex Hormones, and Anterior Cruciate Ligament Injury. J. Athl. Train. 37, 275-278.

O5.6 Alpha suppression as an electrophysiological biomarker of motor drive inhibition during programmed lifts with unexpected sensory consequences

Oscar Ortiz[1], Victoria Chester[1], Adam Wilson[1], Usha Kuruganti[1], Daniel Blustein[2]
[1]University of New Brunswick, [2]Acadia University

BACKGROUND: The ability to manipulate objects in dynamic environments relies on predictive and online mechanisms based on the expectations of the object's properties, such as its expected weight. Differences in expected and actual sensory consequences can drive corrective responses to successfully perform an erroneously planned movement. Having a real-time neural biomarker for this process could improve the control of neuroprostheses by providing algorithms with a signal related to corrective responses. Cognitive neuroscience has shown that higher levels of activity in the alpha range (8-12 Hz) of the electroencephalogram (EEG) signals have the potential to be a biomarker for inhibition of functional regions of the brain. However, limited work has been undertaken to test whether alpha-inhibition can also reflect motor-control related mechanisms. PURPOSE: Here we assess motor-related changes in alpha activity over functional regions of interest (RoI) during reach, grasp-and-lift (GAL) movements using an open source-dataset. METHODS: The dataset (WAY-EEG-GAL: Luciw, Jarocka, and Edin 2014 [URL: https://www.nature.com/articles/ sdata201447]) consists of over 3,900 trials of twelve participants (age 19-35, 8 female, 4 male) performing GAL movements of a custom object whose weight and surface friction properties were changed unpredictably between trials. EEG signals were collected using a 32-channel system. RESULTS: For trials manipulating weight, a repeated-measures ANOVA [2 x 2 x 10 factor design with expected weight (less expected force required, more force required), RoI (left central, right central) and time window (baseline-1000 ms in steps of 100 ms)] showed an interaction effect of the expected grip force required and time window ($F(20, 220) = 2.70$, $p < 0.001$) and a three-way interaction of expected grip force required, RoI, and time ($F(20,220) = 1.78$, $p<0.05$) on cortical alpha activity (Figure 1). Post-hoc analysis with Bonferroni corrections indicated that the left central region showed a greater alpha activity in trials programmed for high grip force against trials programmed for low grip force between 700 ms ($t(11) = -3.35$, $p < 0.05$) and 800 ms ($t(11) = -2.48$, $p < 0.05$) after contact with the object (Figure 1. H, I). No significant differences in alpha activity were found in error processing areas (fronto-parietal region) between expected and unexpected conditions.

CONCLUSION: This study aimed to use EEG features related to error correction to examine how different regions of the brain are engaged in a motor task. These results suggest that alpha activity can reflect error-related motor inhibition over the central regions but is not able to reflect higher engagement of the error-processing areas related to comparisons between the actual and predicted sensory consequences. Understanding electrophysiological biomarkers during movement can help to identify indicators of mental workload and may drive improvements in brain-machine interfaces.

Oral 6 – Electrical Myostimulation

O6.1 Cortical and spinal excitability adaptations following neuromuscular electrical stimulation applied to the triceps surae

Riccardo Borzuola[1], Federico Quinzi[1], Martina Scalia[1], Francesco Di Russo[1], Andrea Macaluso[1]
[1]*Università di Roma "Foro Italico"*

BACKGROUND AND AIM: Neuromuscular electrical stimulation (NMES) has been widely used in recent years to preserve, restore, or enhance muscle mass and function in healthy and injured individuals (Vanderthommen and Duchateau 2007). Several researchers indicated that contractions that are produced by a combination of NMES and voluntary contractions (NMES+) could constitute a complementary training modality, which could lead to additional neuro-physiological effects (Lagerquist 2016). However, a more in-depth analysis of the mechanisms underlying NMES+ is warranted to fully understand the effectiveness of this technique and provide key insights into the methodological aspects of NMES. The aim of this study was to investigate acute responses in spinal excitability and cortical activation of the primary (S1) and secondary (S2) somatosensory areas following three experimental conditions: NMES superimposed to voluntary isometric contractions of the ankle plantar-flexor muscles (NMES+ISO); passive NMES; and voluntary isometric contractions only (ISO). METHODS: Healthy young adults (n=11) participated in the study. They were asked to maintain an ankle plantar-flexor torque of 20% MVIC for 15 contractions (6s contraction/6s rest) during each experimental condition. NMES (50Hz, 400µs) were delivered over the triceps surae muscle, while the intensity of stimulation was adjusted to achieve 20% of MVIC for each contraction. Surface electromyography (sEMG) was used to record H-reflex and motor waves following percutaneous stimulation of the posterior tibial nerve. A small motor wave was kept constant throughout the experiment, to accurately compare H-reflexes (Zehr et al. 2002). MVIC of ankle plantar flexors was assessed with a dynamometer in a semi-reclined position. H reflex and MVIC were assessed before and after each condition. During baseline and post-treatment assessment, EEG was recorded (2500 Hz) by means of 64 active electrodes. The amplitudes and latencies of the following components were detected: P40 at CPz and CP2 electrodes and P100 at PO3 and POz electrodes after 40 and 100 ms after the H-reflex stimulation. RESULTS: H-reflex amplitudes significantly increased by 13% ($p < 0.01$) and decreased by 10% ($p < 0.05$) following NMES+ISO and passive NMES, respectively, compared to baseline; there was no significant change in reflex responses following ISO. The amplitude and latency of P40 and P100 components remained unaltered after the experimental conditions. CONCLUSIONS: These findings indicate that NMES superimposed to voluntary isometric contractions of the ankle plantar-flexors produces an acute potentiation of the soleus H-reflex. This could be associated to a combination of greater motor neuronal and spinal excitability. However, cortical activation of S1 and S2 somatosensory cortices was not influenced by the three conditions. These findings provide novel information on the neurophysiological mechanisms underlying electrical stimulation, suggesting that NMES+ISO could constitute a valid training modality, with even greater advantages compared to passive NMES or voluntary exercise only.

O6.2 Development of a coaching system for functional electrical stimulation rowing: a validation study

Shirin Tajali[1], Pirashanth Theventhiran[2], Gongkai Ye[2], Kai Lon Fok1[3], Hikaru Yokoyama[4], Kento Nakagawa[5], Kei Masani[2]
[1]University Health Network, [2]University Health Network, University of Toronto, [3]University Health Network,University of Toronto, [4]University of Tokyo, [5]Waseda University

BACKGROUND AND AIM: Functional electrical stimulation (FES) rowing has substantial effects on cardiovascular health in individuals with spinal cord injury. Currently, manual stimulation control where stimulation switching is operated manually by the rower has been mostly utilized. However, it takes time to obtain the skill to initiate FES at an optimal time. Furthermore, improper timing may impair coordination between upper and lower limbs, preventing individuals from receiving the full benefits of this exercise. Currently, there is no study investigating the effects of real-time audiovisual feedback on the optimal range for FES administration during FES-rowing exercise. Therefore, the purpose of this study was to develop a coaching system that can help rowers to initiate FES at an optimal time. METHODS: We first determined the optimal range for FES application using electromyography (EMG) activity of left quadriceps muscle in 10 able-bodied individuals (AB). We mainly focused on the EMG activation of knee extensor muscles including vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF) as they were found to be the primary muscles responsible for knee extension during the drive phase of a rowing cycle. Then, we evaluated the effects of the coaching system on the time of button pressing, total work, and power outputs in 7 AB. RESULTS: It was found that the activation of VL began consistently before the seat reaches the anterior-most position. Findings of the coefficient of variations (CVs) of the seat position at the onset of muscle activation across 30 consecutive strokes showed that the CV for VL is significantly clustered at the lower CV region and at around 100-150 mm of the seat position, while, for the other muscles, it is scattered in wider regions (VL: 15.42 %, VM: 26.10%, RF: 35.82 %). Therefore, the mean of seat position at the onset of VL was used as the variable navigating the switch timing in the coaching system. Our results also demonstrated that CV for seat position at the time of button pressing was significantly smaller in the coaching than no-coaching condition (CV coaching: 19.00, CV no-coaching: 12.07, $P < 0.05$). In addition, the median of work and power outputs were significantly higher in the coaching than the no-coaching condition (work coaching: 109.74 J, work no-coaching: 65.25 J, $P<0.05$; power coaching: 19.10 W, power no-coaching: 16.48 W, $P<0.05$) indicating an improved performance during FES-rowing exercise. CONCLUSIONS: The coaching system can provide the optimal timing for FES in the rowing exercise, potentially leading to the improvement of rehabilitation effects.

O6.3 Acute and short-term effects of transcutaneous electrical nerve stimulation on motor unit discharge characteristics and corticospinal excitability

Simon Avrillon[1], Julio Cesar Hernandez Pavon[1], Jose Pons[1]
[1]Shirley Ryan AbilityLab

BACKGROUND AND AIM: Transcutaneous electrical nerve stimulation (TENS) consists of applying an electrical current at low intensity and high frequency to target the recruitment of sensory fibers. Thus, TENS can acutely change motor unit discharge characteristics in the targeted muscle through spinal loops. Additionally, TENS can impact the central nervous system to increase corticospinal excitability. In this study, we first compared the acute effect of three TENS patterns on motor unit discharge characteristics from the first dorsal interosseous (FDI). We then compared measurements of

corticospinal excitability before and after a session of TENS. METHODS: 11 healthy adults (age: 31±10 yrs.) participated in the study. The experimental session consisted of a series of isometric abductions of the right index finger at 10% of the maximal voluntary contraction. We compared contractions without stimulation with three complementary TENS patterns: Pattern #1, stimulation of the right median nerve, Pattern #2, stimulation of the left FDI muscle belly, Pattern #3, stimulation of both the median nerve and the left FDI muscle belly. We delivered each stimulation pattern during 30s windows centered with the middle of the plateau. We assessed changes in motor unit discharge characteristics and common input to motor units before and after the TENS by identifying and tracking motor units from decomposed high-density surface electromyography (HDsEMG) signals. Due to the absence of stimulation artifacts during Pattern #2 and the control condition, we also compared these values during the stimulation. We assessed the corticospinal excitability before and after the session by comparing the amplitude of motor potentials evoked with transcranial magnetic stimulation. We also estimated persistent inward currents by identifying and tracking motor units during 30 s triangular isometric contractions (i.e., Delta F method). We performed our statistical analyses using linear mixed effect models. RESULTS: We did not find an effect of condition on motor unit discharge rates and HDsEMG amplitude before and after the stimulation. The level of common input increased for the control condition while it did not change for the three TENS patterns. During the stimulation, the HDsEMG amplitude increased for pattern #2 while it did not change for the control. The level of common input increased for the control condition while it did not change for pattern #2. After the TENS session, MEPs amplitudes decreased at 110% of the rest motor threshold (rMT), increased at 130% rMT, with no significant differences at 120% rMT. Delta F increased after TENS. CONCLUSIONS: These results suggest that TENS can acutely modulate motor unit discharge characteristics during the stimulation with limited short-term effect once the stimulation stops. TENS can also modulate corticospinal excitability through supraspinal and spinal processes.

O6.4 Modelling in-vivo human motoneurons via high-density electromyography decomposition and metaheuristic optimization

Rafael Ornelas Kobayashi[1], Jan Buitenweg[1], Utku Yavuz[1], Massimo Sartori[1]
[1]*University of Twente*

BACKGROUND AND AIM: Alpha-motoneurons (MNs) are essential for the generation of movement. Based on their individual electrophysiological properties, MNs sample the common synaptic input (CSI) received by the entire pool (Farina et al., 2014). The summated activity of all MNs results in the neural drive to muscle (ND). Therefore, in order to understand human movement, we must first gain insight into MNs individual properties and firing behavior. In this project, we combine high-density electromyography (HD-EMG) decomposition, biophysical neuronal modelling and metaheuristic optimization to create computational models of human MNs, with known electrophysiological properties, able to reproduce in vivo MN discharges. METHODS: HD-EMG was recorded from the tibialis anterior muscle of a healthy male subject performing ramp isometric ankle dorsi-flexion on a dynamometer chair (Biodex multi joint system) at 10, 20, 30, 40 and 50% MVC. Convolutional blind-source separation (Holobar, 2014) was applied to HD-EMG recordings to decode in vivo MN discharges. For each MVC level, decoded discharges were summed and low-pass filtered to derive the corresponding ND and, thus, the CSI received by the MN pool (Farina et al., 2014). MN models driven by derived CSI were created for every decoded spike train. Genetic algorithm optimization was then performed on each MN model to determine the soma size and ionic channels activation rates (i.e. betaQ and alphaQ) that minimize the error in discharge rate, recruitment time and spike match (Lynch & Houghton, 2015). This way, we created digital copies, with known electrophysiological features, of each in vivo decoded MN. Driven by the CSI derived from each MVC recording, we simulated the output of all digital MNs and quantified root mean squared error (RMSE) and absolute error (E) in recruitment time and average discharge rate at plateau between digital and in vivo MNs. RESULTS: Soma size and potassium channel dynamics of all MNs determined by the optimization algorithm are shown in figure 1.A. Experimental and simulated MNs exhibited similar firing characteristics (figure 1.B), achieving RMSE = 1.69Hz and a mean E = 0.544Hz in average discharge rate, and RMSE = 0.133s and mean E = 0.0004 in recruitment time (figure 1.C). CONCLUSIONS: The hereby presented approach enables the non-invasive estimation of the electrophysiological features of human MNs, which allows the creation of subject-specific computational MN models (digital copies) that exhibit the same firing characteristics as their in vivo counterparts. The hereby presented approach enables the non-invasive estimation of the electrophysiological features of human MNs, which allows the creation of subject-specific computational MN models (digital copies) that exhibit the same firing characteristics as their in vivo counterparts. This will enable the development of detailed models for studying the specific neuronal interactions underlying human movement, as well as the implementation of model-based neuronal controllers for wearable robots and neurorehabilitation technologies.

O6.5 PIC a chair and relax: weaker Persistent Inward Currents in motoneurons during whole-body relaxation

Ricardo Mesquita[1], Janet Taylor[1], Gabriel Trajano[2], Jakob Skarabot[3], Ales Holobar[4], Basílio Gonçalves[5], Anthony Blazevich[1]

[1]Edith Cowan University, [2]Queensland University of Technology, [3]Loughborough University, [4]University of Maribor, [5]Griffith University

BACKGROUND AND AIM: Serotonin and noradrenaline release in the spinal cord are critical to motoneuron firing. Without the influence of these neuromodulators, we would not be able to produce more than 40% of our maximum motor output. An important part of this neuromodulation is the activation of persistent (long-lasting) inward currents (PICs) that make motoneurons more responsive to excitatory input. Because arousal state and level of voluntary activity might influence neuromodulation, we examined the effect of whole-body relaxation (WBR) on PIC strength in plantar flexor motoneurons using the well-established paired motor unit (MU) technique. METHODS: High-density surface electromyograms (HDsEMG) of the gastrocnemius medialis were recorded from a grid of 32 equally spaced electrodes (GR10MM0804, 10-mm inter-electrode distance; OT Bioelettronica, Italy). 20-s ramp isometric plantar flexor contractions were performed to 20% of maximal voluntary torque by 20 participants (10 women) in the chair of a dynamometer. Three trials were performed in both control and WBR conditions, in the latter of which participants were asked to deliberately relax while listening to relaxing piano music. HDsEMG signals were decomposed into individual MU discharge events and tracked between conditions. Two trials from each condition were selected and PICs estimated through a paired MU analysis, which quantifies MU recruitment/derecruitment hysteresis. The smoothed firing rate of a lower-threshold MU (control unit) was used as a proxy for the level of net excitatory input to a higher-threshold MU (test unit) and the difference in estimated input at the test unit's recruitment and derecruitment constituted the ΔF (change in frequency) value. A repeated-measures nested linear mixed effects model analysis of the whole sample of test units was conducted to examine the effect of WBR on ΔF. RESULTS: 174 MUs were decomposed, with 391 pairs (101 test units) included in the ΔF analysis and tracked between conditions. The estimates of PIC strength (ΔF) in control and WBR conditions were 3.51 [2.99, 4.03] and 3.03 [2.51, 3.54] Hz, respectively, revealing a significant ~13.7% decrease ($p < 0.001$). There was no evidence of significant difference in ΔF across MU recruitment thresholds or between men and women ($p > 0.05$). CONCLUSION: These findings suggest that WBR reduces the contribution of PICs to gastrocnemius medialis motoneuron firing during a low-intensity contraction. Given that PIC strength is proportional to the level of neuromodulatory drive, this effect is consistent with an attenuation of serotonergic and noradrenergic release associated with decreases in whole-body muscular activity and global stress levels, respectively. This demonstrates the potential to reduce PICs through non-pharmacological, neuromodulatory interventions such as WBR.

O6.6 Streamlined Approach to Optimal Estimation of Time-Varying EMG Standard Deviation (a.k.a. EMG Processing)

Edward Clancy[1], He Wang[1], Kiriaki Rajotte[1], Haopeng Wang[1], Chenyun Dai[2], Ziling Zhu[1], Xinming Huang[1]
[1]*Worcester Polytechnic Institute,* [2]*Fudan University*

BACKGROUND & AIM: Many studies utilizing the surface electromyogram (EMG) estimate its standard deviation (EMGσ or "processed EMG") as a function of time. Advanced processors include the sequential steps of: 1) a highpass filter at 10-20 Hz, to attenuate motion artifacts and remove DC offsets; 2) notch filters, to reject power line fundamental and harmonic frequencies; 3) a whitening filter, to temporally uncorrelated signal samples; 4) an absolute value or square law detector; 5) a lowpass "smoothing" filter, at ≤1-2 Hz; 6) a square root re-linearizer, only if a square law detector was used; and 7) resting noise correction. Noise correction requires an estimate of the EMG variance from a rest recording. Signal whitening is required, since EMG is naturally correlated in time and, thus, not equally represented across frequency. Whitening equalizes the contributions of all signal frequencies. It is similar to counting individual votes at the ballot box of an election, rather than conducting a "voice vote" in which louder speakers contribute disproportionately (and unfairly) to the vote outcome. Whitening is the most technically challenging processing step. It requires designing a filter whose magnitude response is the inverse of the magnitude spectrum of the EMG signal. Historically, such filters are calibrated to the spectral shape of each EMG channel for each subject, requiring collection and processing of calibration data. This complexity has led many researchers to omit this step, with a "noisier" processed EMG resulting. METHODS, RESULTS & CONCLUSIONS: Recently, methods have emerged to whiten EMG data using far simpler techniques. We contrasted four methods in force-varying contraction tasks about the elbow (N=64 subjects) [Wang et al., Sensors 21, 5165, 2021]. Whitening filters calibrated to the EMG magnitude spectrum of each subject produced a best performing average EMG-force error of 4.74% maximum voluntary contraction (MVC). After forming a single "universal" whitening filter representative of all subjects, error was 4.83% MVC. Potvin and Brown [JEK 14(3):389-399, 2004] suggested whitening using a low-order highpass filter, with a high-valued cut-off frequency (≥ 490 Hz) optimized to each experiment. This filter had an EMG-force error of 4.89% MVC. Finally, a first backward difference filter used as a whitener yielded an error of 4.91% MVC. None of these average errors was different when tested statistically. But, each significantly reduced error compared to unwhitened processing (5.55% MVC). The highpass filter and first difference filter have shapes very similar to subject-specific whitening filters, at least up to a frequency of 600-800 Hz (i.e., the primary bandwidth of EMG signals). The first difference filter requires no calibration or algorithm design decisions. It is an excellent whitening filter choice for many applications, and can be implemented with one line of MATLAB code {EMGwhite=filter([1 -1],1,EMGin);}.

O6.7 Multichannel magnetomyography provides robust separability of motor unit action potentials: a simulation study

Thomas Klotz[1], Lena Lehmann[1], Franceco Negro[2], Oliver Röhrle[1]
[1]University of Stuttgart, [2]Università degli Studi di Brescia

BACKGROUND AND AIM: Within the last 20 years, non-invasive motor unit (MU) decomposition techniques have become available by combing HD-sEMG and blind source separation algorithms [1]. However, applying source separation algorithms to sEMG often yields incomplete results. This is particularly true as subcutaneous fat acts as low pass filter, compressing the spatial variability of the observable motor unit action potentials (MUAPs). Alternatively, the electrical excitation of skeletal muscles can be measured via magnetomyography (MMG). Non-invasive MMG provides a higher spatial selectivity than sEMG and hence could improve the accuracy of MU decompositions [2]. In the past, several technical challenges have limited the practical use of MMG. Only recently, a novel generation of sensor system has become available and shown that MMG will become feasible for biomedical applications within the next years [3]. Here we use an in silico modelling framework [2] to test the hypothesis that MMG can uplift the accuracy of state-of-the-art motor unit decomposition techniques. METHODS: We use a computational model [2] to simulate the electric and magnetic MUAPs for a population of muscles. We use the knowledge on the MUAPs to estimate an upper bound for the decomposability of the corresponding EMG and MMG during voluntary contractions. To do so, we closely follow the steps of state-of-the-art decomposition algorithms (e.g. [1]). That is, (i) extending the respective interference signal, (ii) whiten the extended signal and (iii) correlating the pre-processed signal with the whitened MUAPs. RESULTS: While HD-sEMG is the current gold-standard for non-invasive MU decomposition, our results show decomposition accuracy could be strongly improved by measuring MMG instead of EMG. This is particularly true when employing vector magnetometers for MMG recordings. For example, for low MVC levels an average rate of agreement (RoA) of 92% has been achieved by decomposing virtual vector MMG data. In comparison, from the corresponding virtual sEMG signals the average RoA was 62%. Further, when increasing the thickness of subcutaneous fat by 2 cm for the virtual MMG signals the average RoA decreased by 33% and by more than 40% for the virtual sEMG signals. CONCLUSIONS: Within that work we show that MMG could become a game-changer technology for non-invasive MU decomposition. In the future, this potential needs to be explored and tested experimentally. REFERENCES: [1] Negro et al. "Multi-channel intramuscular and surface EMG decomposition by convolutional blind source separation" Journal of Neural Engineering (2016) [2] Klotz et al. "Investigating the spatial selectivity of EMG and MMG based on a systemic multi-scale model" arXiv preprint (2021) [3] Zuo et al. "Miniaturized magnetic sensors for implantable magnetomyography" Advanced Materials Technology (2020)

Friday June 24, 2022

Oral 7 – Motor Control and Motor Learning

O7.1 Dyadic haptic training improves ankle tracking performance but does not accelerate learning of the task

Daniel Ludvig[1], Sangjoon Kim[2], Yue Wen[2], Emek Baris Küçüktabak[1], Matthew Short[1], Jose Pons[2]
[1]Northwestern University, [2]Shirley Ryan AbilityLab

BACKGROUND AND AIM: Rehabilitation therapies for pathologies that alter locomotion often involve re-training individuals with the proper limb and joint angles. Determining the most effective strategy to learn joint angle trajectories could be of great value in accelerating rehabilitation following injury. One paradigm that has been shown to accelerate motor learning involves haptically coupling two participants together in a dyad. When individuals are haptically partnered in a dyad, the trajectory tracking performance of both partners improves. However, there is disagreement whether this improved performance persists once individuals return to tracking the trajectory solo. The tasks that have shown this dyadic tracking improvement, consisted of 2 degree-of-freedom (DOF) arm endpoint tracking, and it remains unknown if this same benefit of dyadic pairing exists for 1 DOF ankle angle tracking. The aim of this study was to determine if dyadic haptic pairing improves performance in ankle angle trajectory tracking and whether this increase in performance persists after the dyadic pair are disconnected. METHODS: Twelve pairs of unimpaired subjects participated in this study. Each subject had their right foot attached to an ankle robot, which was programmed to minimize the interaction torque between the foot and the robot, and form a virtual haptic connection between the dyadic pairs. Subjects completed 6 blocks of 11 28-s trials where they tracked a multi-sine trajectory with net amplitude of 0.33 rad and frequencies from 0.2-0.5 Hz, aided by visual feedback. Each block used random phases, preventing memorization of the pattern across blocks. Two different block types were used in a randomized order: one with only solo tracking trials, and one with alternating solo and dyad tracking trials. In the dyad tracking trials, subject pairs were haptically connected via a virtual spring with a stiffness of 20 Nm/rad. Tracking performance was measured by computing the root-mean-square error (RMSE) between the desired trajectory and the actual angle. Motor learning was estimated by fitting the RMSE to a linear mixed-effects model with trial number as the independent variable, and block and trial type as fixed factors. RESULTS: Haptic dyadic pairing resulted in an improvement in tracking performance, but no changes in the rate of learning compared to solo training. We found that subjects were able to learn the task, as RMSE decreased by 0.3% with each trial. Haptically connecting the dyads resulted in a decrease in RMSE by 8.7% compared to the solo trials. However, subjects did not learn the task any faster during the dyad trials, nor did the improvement in performance persist in the solo trials following the dyad trials. CONCLUSION: Though hapitcally connecting individuals into a dyad improved their performance on an ankle trajectory tracking task, it did not result in faster learning or performance improvements after dyadic pair is disconnected, raising doubt of its efficacy in accelerating individual 1 DOF motor learning.

O7.2 Location-specific cutaneous electrical stimulation of the foot sole modulates corticospinal and spinal excitability to the plantar and dorsi-flexors during standing

Davis Forman[1], Gagan Gill[1], Joanna Reeves[2], Janet Taylor[3], Leah Bent[1]
[1]University of Guelph, [2]University of Bath, [3]Edith Cowan University

BACKGROUND AND AIM: Non-noxious electrical stimulation to distinct locations of the foot sole evokes location-specific cutaneous reflex responses in lower limb muscles; stimulation to the heel facilitates the plantar flexors but inhibits the dorsiflexors, while metatarsal stimulation results in a complete reversal of these effects [1]. These reflexes occur at latencies that may enable them to be mediated via a transcortical pathway [2], however, it is presently unclear whether or not cutaneous foot sole stimulation influences measures of corticospinal and/or spinal excitability. METHODS: Corticospinal excitability to the soleus, medial gastrocnemius (MG), and the tibialis anterior (TA) was measured in 16 participants using motor evoked potentials (MEPs). Spinal excitability was measured in 8 of the original participants using cervicomedullary motor evoked potentials (CMEPs). While participants stood, measurements were collected with and without preceding cutaneous stimulation applied to either the heel (HEEL) or metatarsal (MET) locations of the foot sole. Evoked potentials were elicited to coincide with the arrival of the cutaneous volley at either the motor cortex (for MEPs) or spinal cord (for CMEPs). RESULTS: For both plantar flexors, stimulation at the HEEL significantly increased MEP (Soleus: 34% increase, p=0.04, MG: 55%, p=0.017) and CMEP (Soleus: 146%, p=0.047 and MG: 140%, p=0.015) amplitudes, although MEP and CMEP amplitudes were unchanged with stimulation at the MET location for both the soleus and MG. TA MEPs were unchanged with cutaneous stimulation at either location, but TA CMEPs increased as a main effect of cutaneous foot sole stimulation (150% increase, p=0.05), with no difference between stimulation location. Over most of the stimulation and muscle combinations, increases in CMEPS were found to be significantly larger than MEPS, indicating that increases in spinal excitability likely explain most of the increase observed in MEPS. While there may be a cortical contribution to these reflexes, the larger change observed in the CMEP suggests that excitability at a supraspinal level likely decreased, which could be due to a net change in the excitability of intracortical circuits. CONCLUSIONS: This study demonstrates possible functional importance of cutaneous stimulation in motor control; the withdrawal of cortical drive following cutaneous afferent stimulation might allow for other pathways to better respond to cutaneous stimulation originating at the foot sole. References: [1] Nakajima et al. (2006). Exp Brain Res, 175:514-525. [2] Nielsen et al. (1997). J Physiol, 484(3):791-802.

O7.3 Does low back muscle fatigue task specific modify the recruitment pattern of lumbar muscles?

Emile Marineau[1], Justin Roy[1], Bastien Couëpel[1], Mathieu Tremblay[1], Martin Descarreaux[1], Jacques Abboud[1]
[1]*Université du Québec à Trois-Rivières*

BACKGROUND AND AIM: Superficial muscles of the lower back are characterized by multiple motor end plates and their segmental innervation. In a recent study, a clear distinction in the motor unit territories between the cranial (L1 to L3) and caudal (L3 to L4) region of the longissimus muscle was observed. Moreover, previous studies showed that lumbar muscle activation spatially moved caudally during low back fatigue-induced tasks. However, it is yet unknown if such recruitment strategy of lumbar muscles is dependent on the fatigue task characteristics. The aim of this study is to identify whether lumbar erector spinae muscle recruitment is modulated by the fatigue task characteristics. METHODS: Twenty healthy participants will be recruited to perform two different low back muscle fatigue protocols. The first fatigue task corresponded to the modified version of the Sorensen test executed on a 40° Roman chair with participants' trunk unsupported. The second fatigue task was performed on a 40° incline table with lower limbs unsupported (Reverse Sorensen). Both tasks were performed at 20% of their maximal voluntary isometric contraction until exhaustion. Right and left lumbar erector spinae activity was recorded using high-density surface electromyography (2 arrays of 64 electrodes). Participants were given a 30-minute break between both tasks and the order of the task was randomized between participants. The median frequency (MDF) and the medio-lateral (x-axis) and cranio-caudal (y-axis) coordinates of the centroid (spatial distribution of muscle activity) were computed and divided in 6 equal time frames. T-test were conducted to compare neuromuscular fatigue on MDF slopes between tasks. Repeated measures ANOVAs were conducted to compare the centroid location over time (6 times) and between tasks. RESULTS: Based on six participants, preliminary results show a bilateral decreased lumbar muscle MDF during both tasks (Sorensen: MDF slope left=-4.39 (±2.70 Hz/s); right=-4.74 (±2.29 Hz/s); reverse Sorensen: MDF slope left=-2.82 (±2.11 Hz/s); right -2.97 (±2.97 Hz/s). No

statistical difference was observed between task (MDF right p=0.305; MDF left p=0.165). Statistically significant differences in centroid migration pattern were observed between the two tasks (figure 1). On the left side, interaction and time effects were significant for the Y-axis (interaction p=0.027; time effect p=0.030; Right side: interaction p=0.054; time effect p=0.751). X-axis centroid location was similar between tasks and over time. CONCLUSIONS: These results support a regional activation pattern of superficial lumbar erector spinae muscles and suggest that strategies of regional activation are modulated according to task characteristics, during tasks that induce a similar level of fatigue.

O7.4 Is acetylcholine a neuromodulator of muscle activation?

Justin Kavanagh[1]
[1]*Associate Professor*

BACKGOUND AND AIM: The relationship between motor function and cholinergic circuitry is complex, where only a few human studies have described how acetylcholine affects intracortical neural activity within the motor cortex. The aim of this study was to assess the functional effects of a muscarinic receptor blockade on corticospinal excitability during muscle contractions, and during relaxation from muscle contractions. METHODS: Single pulse TMS was used to obtain motor evoked potentials (MEPs) in healthy adults (age range: 20-24 yr). Two experiments were performed that were placebo-controlled, two-way, crossover trials. For both experiments, promethazine 25 mg was used to cause a muscarinic receptor blockade in the central nervous system. Experiment 1 (n = 10) obtained MEPs from the biceps brachii during brief 10% MVC, 25% MVC, 50% MVC, 75% MVC and MVCs. Experiment 2 (n = 13) obtained MEPs from the abductor digiti minimi immediately following 50% MVC, MVCs that were 10 s in duration and MVCs that were 60 s in duration. MEP data was normalised to the respective muscle maximal compound action potential (Mmax) for all measurements. RESULTS: The antimuscarinic blockade have no effect on standard input-output curves that were collected for each experiment. In experiment 1, where measurements were made during muscle contractions, there were no main effects of drug on MEP area. However, there was an interaction effect between drug and contraction intensity MEP silent period duration (p = 0.049), where muscarinic blockade caused an increase in silent period for the antimuscarinic condition during the unfatigued 75% and 100% MVCs. In experiment 2, where measurements were made following muscle contractions, main effects were detected for MEP area following the 10 s MVC (p = 0.019) and the 60 s MVC (p = 0.040) where MEP area was greater for the antimuscarinic condition. CONCLUSIONS: These experiments demonstrated that corticospinal excitability was only influenced by cholinergic effects following muscle contractions where voluntary drive to the muscle was high. Given that the TMS evoked silent period increased during the muscle contractions of experiment 1, it appears that some degree of cortical inhibition is evoked via cholinergic mechanisms. However, this cortical inhibition did not cause a discernible effect on activation of the motor pathway.

O7.5 Motor learning and Sensorimotor Integration during a Novel Force-Matching Task in Young Adults with Attention-Deficit/Hyperactivity Disorder

Heather McCracken[1], Bernadette Murphy[1], Ushani Ambalavanar[1], Paul Yielder[1]
[1]*Ontario Tech University/UOIT*

Background: Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder that exhibits unique neurological and behavioural characteristics 1, 2. Those with ADHD often have noted impairments in motor performance and coordination, including during tasks that require force modulation 3, 4. There are alterations in the processing of somatosensory stimuli 5 and the integration of multisensory stimuli 6. However, it is unknown how motor learning and performance may be implicated and whether there are neural markers relevant to these differences in young adults with ADHD. This work can provide insight into the role of altered neural processing and sensorimotor integration (SMI), particularly in response to a motor learning paradigm requiring force modulation. Methods: This work compared adults with ADHD (n = 5) to neurotypical controls (n = 5), utilizing a novel force-matching tracking task (FMTT), where participants used their right-thumb to match a trace template that varied from 2 - 12% of their APB MVC. This motor task was completed in pre, acquisition, and post blocks, and participants completed a retention and transfer test 24 hours later. Median nerve somatosensory-evoked potentials (SEPs) were collected pre and post motor acquisition. SEPs are named based on their polarity and latency and are reflective of specific neural processes and structures. For example, a negative SEP peak occurring 30ms post-stimulation is labelled N30; the N30 is reflective of sensory integration. SEPs were stimulated at two frequencies, 2.47Hz and 4.98Hz, and 1000 sweeps were recorded using 64-electrode electroencephalography (EEG) at 2048Hz. SEP amplitude changes were normalized to each participant's baseline values for that peak. Preliminary Results: Behavioural: Both groups improved at post measures, with further improvements at retention for absolute and normalized values. For performance absolute percent error, the control group had reduced error at all phases including baseline, compared to those with ADHD. When post, retention, and transfer performance were normalized to pre-values, those in the ADHD group had greater performance improvements compared to neurotypical controls. Neurophysiological: The N11 remained stable in the ADHD group and increased in controls (1.41 ± 0.37), whereas the N13 decreased in the ADHD group (0.83 ± 0.14) and increased in controls (1.22 ± 0.39). The ADHD group had a reduced N18 (0.90 ± 0.09), while controls increased (1.69 ± 1.08). The N30 increased slightly in the ADHD group (1.08 ± 0.26) while controls increased more (1.33 ± 0.37). Discussion: This work is the first to utilize neurophysiological measures via SEPs in conjunction with a behavioural motor learning paradigm to assess processes involved in motor learning in adults with ADHD. Those with ADHD appear to have reduced performance on tasks dependent on force-modulation but have more pronounced improvements compared to neurotypical controls. There are unique neural difference between groups, particularly the N13, N18, and N30. Moving forward, increasing the sample size will help to further understand the mechanisms behind these preliminary findings.

O7.6 Reliability of contralateral associated EMG activity during unilateral strength testing

Carli Mentzer[1], Alisa Soloveva[1], Blake Ruplinger[1], Caleb Voskuil[1], Joshua Carr[1]
[1]*Texas Christian University*

Background and aim: During unilateral motor tasks, there is involuntary activation of the contralateral homologous muscle groups that are detectable with surface electromyographic (EMG) recordings. This phenomenon is termed associated EMG activity and is seen in pathological states and healthy neurological systems. The magnitude of associated EMG activity increases with the intensity of the task demands, but the reliability of associated EMG activity during strength testing is not well described. The purpose of this experiment was to identify the test-retest reliability of the absolute and normalized associated EMG activity during strength testing in healthy adults. Methods: Following a familiarization session, maximal unilateral one-repetition maximum (1RM) and maximal voluntary contraction (MVC) testing were performed for the dominant and non-dominant elbow flexors in eleven participants. The measurements were completed on two separate visits three-seven days apart. Surface EMG activity was collected from both biceps brachii during all strength testing tasks with bipolar surface electrodes (Trigno, Delsys inc). The procedures were the same during both testing visits and the order of testing was randomized between arms. Following the determination of the 1RM and MVC values, the absolute levels of associated EMG activity in the contralateral biceps brachii were identified. The relative levels of associated EMG activity were then computed by normalizing (%) against the maximal EMG RMS values obtained during the respective task. Test-retest reliability statistics were quantified with intraclass correlation coefficients (ICC), the standard error of the measurement (SEM), and Cohen's d values were computed for the mean comparisons on the absolute (µV) and relative (%) levels of associated EMG activity during maximal strength testing for both arms. Results: There were no significant mean differences for any comparisons (p > 0.38, d < 0.23). The reliability of absolute associated EMG activity during MVC testing was excellent for both arms (ICC: 0.87-0.94; SEM: 10.0-16.4 µV) and for the left (ICC = 0.88; SEM = 26.2 µV), but not the right biceps brachii (ICC = 0.191; SEM = 12.1 µV) during 1RM testing. The reliability of normalized associated EMG activity was moderate-good for both arms during MVC (ICC: 0.68-0.79; SEM: 2.3-2.6%) and 1RM testing (ICC: 0.53 - 0.73; SEM: 2.5-8.8%). Conclusions: These data show that unintentional associated EMG activity in the contralateral homologous muscle during maximal strength testing is generally stable across testing visits despite the considerable interindividual variability. Given the reliability of associated EMG activity during strength assessment, this variable may be a target for biofeedback or may be useful for inferring neural adaptations following an intervention.

Oral 9 – Motor Units

O8.1 Reticulospinal contribution to maximal in vivo motoneuron output in humans

Jakob Skarabot[1], Jonathan Folland[1], Ales Holobar[2], Stuart Baker[3], Alessandro Del Vecchio[4]
[1]Loughborough University, [2]University of Maribor, [3]Newcastle University, [4]Friedrich-Alexander University

BACKGROUND AND AIM: Maximal in vivo motoneuron output is a key determinant of maximal rate of force development in humans, however the origin of inputs underlying maximal motoneuron output remains unclear. The pontomedullary reticular formation consists of large, fast-conducting axons that, via the reticulospinal tract, make mono- and disynaptic connections to alpha motoneurons. The reticular formation plays an important role in motor command generation and production of gross, high-force movement tasks, making it a potential substrate for maximal motoneuron output in humans. In this study, we tested a hypothesis that the maximal motoneuron output will increase in response to a startling cue, a stimulus that purportedly activates neurons in the pontomedullary reticular formation. METHODS: Twenty-two men were required to produce isometric knee extensor force "as fast and as hard" as possible, reaching at least 75% of maximal voluntary force, in response to illumination of a light-emitting diode alone (LED; visual cue, VC), or with the addition of a quiet (visual-auditory cue, VAC; LED + 80 dB) or a loud auditory stimulus (visual-startling cue, VSC; LED + 110 dB). The myoelectrical (EMG) activity of the vastus lateralis (VL) and medialis (VM) were measured with surface grids of 64 electrodes. The EMG signals were decomposed into individual motor unit (MU) spike trains using Convolution Kernel Compensation algorithm. RESULTS: Reaction time was significantly shorter in response to VSC (149±34 ms) compared to VAC (182±46 ms) and VC (276±55 ms; p<0.001). The faster responses to VSC were coupled with greater maximal rate of force development (1503±426 N.s⁻¹) compared to both VC (1255±376 N.s⁻¹, p<0.001) and VAC (1214±388 N.s⁻¹, p<0.001), with no differences between VAC and VC (p=0.358). The average number of discharges per MU per second, constituting the effective neural drive to muscle, was greater in response to VSC (VL: 76±15 pps; VM: 77±15 pps) in comparison with VC (VL: 61±10 pps, p=0.004; VM: 61±14 pps,

p=0.002;) and VAC (VL: 64±10 pps, p=0.005; VM: 61±12 pps, p=0.015), with no differences between VC and VAC (VL: p=0.438; VM: p=0.889). CONCLUSION: Visual-startling cue shortened the reaction time, and increased maximal rate of force development and neural drive. The increased neural drive in response to a startling stimulus suggest a subcortical contribution to maximal motoneuron output in humans, likely originating from the pontomedullary reticular formation.

O8.2 Identifying and tracking motor units using a multi-dimensional representation of their action potentials

Jérémy Liegey[1], Lara McManus[2], Madeleine Lowery[1]
[1]UCD, [2]Trinity College Dublin

BACKGROUND AND AIM: Decomposition of surface electromyography (EMG) recorded with high-density electrode arrays enables identification of motor unit (MU) firing times and their corresponding action potential (MUAPs) templates. It also presents the possibility of tracking MUs across multiple recordings, and in some cases, longitudinally over time [2]. However, methods of identifying action potentials from the same MU that are based on cross-correlation are sensitive to distortions or changes in MUAP shape, such as those due to MUAP superposition and changes in conduction velocity. Here we present a new method to compare MUAPs and identify MUAPs from the same MU based on the multi-dimensionality of high-density EMG data. METHODS: Sets of MUAPs from a 5-channel electrode array were generated using an anatomically based EMG model (N = 20 sets, each containing 25 to 75 MUs) [1]. Duplicate MUAPs were added to the population by distorting selected MUAPs (changing amplitude, conduction velocity and adding noise). Each MUAP was represented as a 4-dimensional (4D) trajectory and trajectories were compared between each possible set of 2 MUAPs. The overall difference between each pair of MUAP trajectories was characterised using 14 features (e.g., feature 1 was the sum of the Euclidean distance between the two trajectories at each point in time in 4-D space). Principal component (PC) analysis was applied to the feature differences, and the three highest PCs were examined in 3D space for different subsets of features. The features subset that resulted in the greatest separation between the cluster containing the duplicate pairs and the rest of the dataset was identified using a forward feature selection method. After determining the optimal feature subset, duplicate pairs were identified using an outlier detection method. This analysis was then applied to experimental data recorded with a 128-channel array (BioSemi Ltd.) and the results compared with a correlation-based template matching approach. RESULTS: The proposed method detected all duplicate pairs in the 20 simulated sets examined (no false negatives or positives). Individual MUs were also successfully tracked across successive experimental trials using the proposed method, Fig1. In comparison, the correlation-based approach detected only 71.65±18.58% of duplicate pairs (cut-off cross-correlation threshold of 0.9). A high number of MUAP pairs were incorrectly identified as being from the same motor unit, with a false positive rate of 82.02±6.79%. CONCLUSION: Comparing MU based on features of their action potential trajectories offers a more accurate method of tracking MUs and could be incorporated into future MU decomposition algorithms to improve the detection of action potentials from the same MU. REFERENCES:[1] Pereira Botelho et al. (2019). PLoS Comput. Biol.,15(8),e1007267. [2] Martinez-Valdes E, Negro F, Laine CM, Falla D, Mayer F, Farina D. J Physiol. 2017;595(5):1479-1496. doi:10.1113/JP273662

O8.3 Real-Time Motor Unit Action Potential Recognition

John Chiodini[1], Michael Twardowski[1], Bhawna Shiwani[1], Serge Roy[1], Paola Contessa[1], Gianluca De Luca[1], Joshua Kline[1]
[1]Delsys & Altec Inc.

BACKGROUND AND AIM: Throughout the history of neuroscience, the understanding of human movement has depended, in part, on our ability to measure the firings of α motoneurons, the final common pathway of inputs from the central nervous system to the muscle fibers they innervate. The study of these anatomical pathways, or motor units (MUs), and their resulting action potentials (MUAPs) in the electromyographic (EMG) signal is a well-established means of interrogating the structure and function of the neuromuscular system. Historically, the process of identifying MUAPs - whether visually or by means of automated algorithms - has generally been limited to low force isometric contractions and offline processing, due to the computational and algorithmic intractability of processing dynamic surface EMG signals, which are nonstationary and contain larger numbers of MUs [1]. METHODS: To address these limitations, we have developed real-time MUAP recognition algorithms capable of identifying and tracking MUAPs during a variety of dynamic activities, building upon previous work in real-time MUAP tracking for myoelectric control [2]. Our algorithm uses a two-stage approach to 1) identify the shapes of individual MUAPs; and 2) track their incidence throughout the sEMG signal. The first stage extracts peak, phase, and contour-based features from the sEMG signal, then performs custom feature vector clustering to identify the MUAPs of each active MU from surrounding MUAPs, noise, and superpositions. Extracted features are used in the second stage to train a real-time non-stationary Hidden Markov Model (HMM) to precisely track MU firings amidst MUAP superpositions and noise in the sEMG signal on a 31.5 ms variable overlapping window. RESULTS: We validated the performance of our algorithms on a database of over 40 EMG recordings from 13 subjects, with over 14 different muscles tested. Data were collected using a 4-pin mini-grid wireless sEMG sensor (Galileo, Delsys Inc.), and processed on a PC with an Intel i7-11700F, 4.9GHz processor, and a NVIDIA RTX 3070 graphical processing unit (GPU). MU identification and tracking accuracy were validated using the reconstruct-and-test method [3], adapted for dynamic contractions. Our results achieved yields averaging 18.2 (+/- 13.0) with > 85% MUAP shape identification and MU tracking accuracy. Processing times exceeded real-time potential, averaging 11.7 (+/- 10.0) ms per 31.5 ms window across over 64,000 windows tested. CONCLUSIONS: These findings demonstrate the feasibility of a real-time construct for recognizing motor unit action potentials within a detected EMG signal. This capability provides first-time access to MUAP information in point-of-care applications to empirically quantify deficits or gains in the neuromuscular system across a multitude of normal human movements. [1] De Luca et al., J Neurophysiol 2015 [2] Twardowski et al. J Neural Eng 2018 [3] Nawab et al, Clin Neurophysiol 2010

O8.4 Consensus for experimental design in electromyography (CEDE) project: High-density surface electromyography matrix

Alessio Gallina[1], Catherine Disselhorst-Klug[2], Dario Farina[3], Merletti Roberto[4], Manuela Besomi[5], Paul Hodges[5]

[1]University of Birmingham, [2]Aachen University, [3]Imperial College London, [4]Politecnico di Torino, [5]The University of Queensland

Background and aim: High-density surface electromyography (HDsEMG) can be used to measure the spatial distribution of electrical muscle activity over the skin. As this distribution is associated with the generation and propagation of muscle fiber action potentials, HDsEMG is processed to extract information on regional muscle activation, muscle fiber characteristics, and behavior of individual motor units. This matrix, developed by the Consensus for Experimental Design in Electromyography (CEDE) project, aims to summarize recommendations on the use of HDsEMG in experimental studies. Methods: The development of the matrix followed a similar process described in other CEDE matrices. First, a draft of the content was developed by the steering committee (composed of three CEDE members, and one early career researcher who led the development of the content). Second, a consensus process was followed using a Delphi approach. The remaining CEDE members (n=18) were invited to participate in this matrix, but four declined to participate because this topic was not within their scope of expertise. The steering committee, the lead investigator, and the coordinator oversaw the project and integrated comments but did not participate in the Delphi process. Results: Two Delphi rounds were completed to reach a consensus on the HDsEMG matrix. Cells of the matrix were organized according to the three most common applications of HDsEMG: regional activation, muscle fiber properties, and single motor unit activity. For each application, the content was prepared in five sections: 1) electrode montage; 2) electrode type and configuration; 3) electrode location and orientation; 4) data analysis; and 5) interpretation. Based on relevance, each section included one or more of the following sub-sections: descriptors, pros, cons, caution, recommended use, non-recommended use, and a summary of information to report. Conclusions: This matrix is intended to help researchers when collecting, reporting, and interpreting HDsEMG data. It is hoped that this document will be used to generate new empirical evidence to improve how HDsEMG is used in research and in clinical applications.

O8.5 Influence of volume conductor and spatiotemporal properties of motor unit action potentials on the number of decomposed motor units from high-density EMG signals

Daniela Souza de Oliveira[1], Andrea Casolo[2], Thomas Balshaw[3], Sumiaki Maeo[4], Marcel Lanza[5], Neil Martin[3], Nicola Maffuli[6], Thomas Kinfe[1], Bjoern Eskofier[1], Jonathan Folland[3], Dario Farina[7], Alessandro Del Vecchio[1]

[1]Friedrich-Alexander University Erlangen-Nürnberg, [2]University of Padova, [3]Loughborough University, [4]Ritsumeikan University, [5]University of Maryland, [6]University of Salerno, [7]Imperial College London

BACKGROUND AND AIM: The decomposition of high-density EMG (HDEMG) signals is essential for the identification and tracking of individual motor units (MUs) during voluntary force contractions. However, one limitation of this method is the variability in the number of detected MUs across individuals and contraction forces, which impedes some applications in research and clinical environments. We aimed at investigating neural and muscular parameters that may be involved in this variability. METHODS: Decomposition algorithms require sparse (non-overlapping) sources in time and space. Therefore, we analyzed the correlation between the number of identified MUs and the synchronization of MU spikes, distribution of MUs in space (spatial sparsity), muscle-electrode distance (proportional to subcutaneous fat thickness), maximum anatomical cross-sectional area (ACSAmax) and single fiber CSA (spatial resolution). Those parameters were obtained through high-density EMG recordings, ultrasound, MRI imaging and muscle biopsy of biceps brachii from two groups of participants - untrained-control (UT = 14) and strength-trained individuals (>3 years of training, ST = 16). They performed ramp contractions with elbow flexors at different target forces (15, 35, 50 and 70% Maximum Voluntary Torque - MVT). We assessed the correlation according to the target forces, combining both groups (UT and ST). A multiple regression model was applied and the relative importance of each predictor to the model was also assessed. RESULTS: For the UT group, fewer MUs were detected (UT: 21.3±10.2 MUs vs. ST: 29.2±11.8 MUs) accompanied by a higher muscle-electrode distance (UT: 4.8±1.4mm vs. ST: 3.7±0.8mm). Considering both UT and ST groups, we found a negative correlation between the muscle-electrode distance and number of identified MUs at lower forces (correlation coefficient $r = -0.60$, p-value<0.01 at 15% MVT; $r = -0.50$, p-value<0.05 at 35% MVT). Moreover, the number of MUs was also positively correlated to the spatial sparsity ($r=0.56$, $p = 0.01$)

and ACSAmax (r = 0.48, p<0.05) at 15%MVT. Synchronization and Fiber CSA presented no significant correlations with the number of identified MUs. In our multiple regression model, we considered all the parameters and divided the target forces into low (15 and 35% MVT) and high (50 and 70% MVT). At low forces (R^2 = 0.44, p<0.001) the muscle electrode distance had a more significant impact on the number of MUs (explaining 19% of the R^2 variance, p = 0.004) along with the spatial sparsity (explaining 13% of the R^2 variance, p = 0.02). At high forces (R^2 = 0.26, p = 0.02), we found a reduced contribution of muscle-electrode distance and spatial sparsity. ACSAmax explained approximately 8% of the variance in the number of MUs at both low and high forces. CONCLUSIONS: This work confirmed, experimentally, the influence of muscle-electrode distance on HDEMG signals. Further, we demonstrated that the decomposition of HDEMG is also affected by other physiological factors. Our findings highlight the importance of a careful interpretation of decomposition results and might help further improvement of decomposition algorithms.

O8.6 Intramuscular recordings of biceps and triceps brachii motor unit activity during ramped, isometric contractions performed as an agonist or antagonist muscle

Justine Magnuson[1], Brian Dalton[1], Chris McNeil[1]
[1]The University of British Columbia - Okanagan Campus

BACKGROUND AND AIM: During voluntary contractions, joint torque reflects the contribution of agonist and antagonist muscles. Based on surface electromyography (EMG) data, the level of antagonist activity (co-activation) increases with contraction intensity, typically reaching ~10% during an isometric maximal voluntary contraction (MVC). Although this indicates activity of many antagonist motor units (MUs), it is unknown if these MUs are recruited at a similar level of neural drive and in a similar order to an agonist contraction. METHODS: Nine healthy participants (four female) performed six ramped, isometric elbow flexions followed by six ramped, isometric elbow extensions. Contractions alternated between targets of 50 and 100% MVC torque, and all were performed with a 10-s ramp up and 10-s ramp down. Bipolar surface EMG and three-to-four fine-wire intramuscular EMG recordings were sampled from the biceps and triceps brachii. To quantify co-activation, root-mean-square (RMS) amplitude of the surface EMG signal during an antagonist MVC was expressed as a percentage of the value during an agonist MVC. RESULTS: During agonist contractions, low-threshold MUs (recruitment threshold <10% MVC torque) were successfully sampled in all participants, with at least two per person and a total of 66 and 58 for biceps and triceps brachii, respectively. Recruitment thresholds of the first isolated MU for 50 and 100% MVC contractions were 1.8 ± 2.4 and 2.5 ± 2.8% MVC torque for biceps brachii and 1.6 ± 1.9 and 1.0 ± 1.1% MVC torque for triceps brachii. Co-activation was 8.4 ± 7.6% for biceps brachii during ramped elbow extensor MVCs and 12.9 ± 7.1% for triceps brachii during ramped elbow flexor MVCs. Despite these findings of appreciable co-activation from surface EMG signals, antagonist single MU activity was recorded in only two of nine participants during elbow extensor contractions and in only one participant during elbow flexor contractions. In these individuals, the first antagonist MU was recorded at 44.2 and 76.3% MVC torque for elbow extensor contractions, and 51.9% MVC torque for elbow flexor contractions. When recruitment threshold is considered in terms of global neural activity, the few biceps brachii MUs recorded during antagonistic contractions were seemingly recruited at an RMS EMG value similar to that of an agonist contraction (mean values of 5.9 and 6.0%, respectively). In contrast, the scant triceps brachii MUs were recruited at higher RMS EMG values when acting as an antagonist (24.4%) compared to agonist (9.6%). CONCLUSIONS: Although there was robust sampling of very low-threshold MUs in all participants during agonist ramp contractions, minimal, if any, activity was detected

from these MUs during antagonist contractions up to maximal torque. When considered along with the pronounced co-activation revealed by the surface EMG data, the results indicate MUs recruited early during an agonist contraction seldom appear to be among those first recruited during an antagonist contraction.

Oral 9 – Robotic Rehabilitation

O9.1 Using Transfer Learning for Generalized Upper Limb Force Modelling during Dynamic Contractions

Gelareh Hajian[1], Mehdi Ansari[2], Evelyn Morin[1]
[1]Queen's University, [2]Blue Hexagon Inc.

BACKGROUND AND AIM: In EMG-based force modelling, generalizing models across individuals is essential for widespread application of these technologies, for example in assistive devices, robotics, and rehabilitation. However, most studies in the field have focused on intra-subject modelling, as developing a generalized model is a challenging problem. Transfer learning (TL) is a deep learning approach in which knowledge is transferred from one model to another, where the data domains are the same. In this work, we investigate the feasibility of using TL to generalize a force model to a new user. We hypothesize, based on the idea of TL, that general, informative features can be learned from large amounts of data generated by multiple users, and then through the TL fine-tuning process, the weights of the last layers of the model will be tuned for the new user, to extract subject-specific features. METHODS: EMG signals were recorded from the long head and short head of the biceps brachii, brachioradialis, and triceps brachii muscles, during dynamic elbow flexion and extension, using four linear high-density (HD)-surface electrode arrays with eight monopolar channels (Bioelettronica EMG-USB2 HD system). Arm movement was recorded using a Shimmer wearable IMU sensor placed on the back of the forearm. Fourteen participants were recruited for this study, and they provided informed consent before the experiment. The experiments were conducted using a Biodex model 840-000 device, which recorded torque data. For each subject, the data were collected in one session with 36 trials in total. A deep multimodal convolutional neural network (dmCNN) model was developed to learn the output force from the EMG (28 channels) and motion signals (9 IMU channels). The dmCNN consists of two CNN models, one with EMG (CNNEMG) and one with IMU (CNNIMU) as input. Each CNN had two convolutional layers with [16, 16] filters for CNNEMG, and [64, 128] filters for CNNIMU. Then a shallow neural network with three dense layers to aggregate all extracted features from EMG and IMU, and weight them to estimate force, was used. For the TL model, we tuned the parameters of the last four layers in the dmCNN model to personalize a generic model for subject-specific force modelling. The results of TL have been compared with a leave one subject out (LSO) scenario, in which we used the developed model only for force modelling on a new user (with no tuning). RESULTS: Our results indicate that the proposed TL technique significantly enhances the performance of force modelling compared to the LSO on a new user. The average of R-squared values increased by 139.6%. We also found that as the number of participants considered in developing the generic model increased, the performance of TL on a new user is improved. The R-squared value increased for one user from 0.016 to 0.54, as the number of users increased from 4 to 13 people. CONCLUSIONS: In summary, we found that the results of using TL for force prediction for a new user were superior to those for LSO. Thus, TL has great potential for generalizing a developed model to a new user, which is highly needed in real-life applications.

O9.2 Intuitive prosthesis control based on residual movements and their goals enables amputees to pick and place objects as with their natural arm

Effie Segas[1], Sébastien Mick[2], Vincent Leconte[1], Rémi Klotz[3], Daniel Cattaert[1], Aymar de Rugy[1]
[1]Univ. Bordeaux, CNRS, INCIA, UMR 5287, [2]ETIS, UMR 8051, CY Cergy Paris Université, ENSEA, CNRS F-95000, [3]CMPR Tour de Gassies

BACKGROUND AND AIM: Externally powered upper limb prosthesis controlled with myoelectric signals suffers a dimensionality problem, where higher amputations require more distal joints to be controlled with less remaining muscles. Following recent attempts at exploiting natural multi-joint coordination for intuitive control of distal missing joints based on remaining stump motion, we propose an original approach that also incorporates information about movement goals. Indeed, recent progresses in computer vision with gaze information indicate that this information could be available to a control system. We showed recently that adding target position and orientation to an Artificial Neural Network (ANN) trained to predict distal joints from proximal (shoulder) motion greatly improves these predictions, as well as human-in-the-loop control of a virtual arm based on them. Here, we present a set of three experiments aiming to extend this finding to a much broader workspace, and to transhumeral amputees for which natural arm movements cannot be collected from their amputated side. METHODS: Participants were required to pick and place bottles of various positions and orientations in a virtual environment, with a virtual arm reproducing movements of their own arm, or with our prosthesis control based on distal joints predicted by the ANN. In Exp1, we collected natural arm movements from 10 able-bodied participants, and tested a prosthesis control based on an ANN trained on the own data from each of those participants (the OWNANN). In Exp2, 12 naive able-bodied participants were tested on a prosthesis control with an OWN-ANN, and with another ANN trained on data from the 10 participants of Exp1 (GENERIC-ANN). In Exp3, 7 transhumeral amputees were tested for control with the same GENERIC-ANN, as well as with their valid arm on the non-amputated side. RESULTS: Exp1 and 2 showed that performances and movement times were identical whether the task was performed with the natural arm, with the OWN-ANN, or with the GENERIC-ANN, despite slightly higher compensatory movements of the shoulder observed with the GENERIC-ANN in Exp2. Next, Exp3 showed that 7 transhumeral amputees were able to perform the same pick-and-place task similarly well with the GENERIC-ANN (on their amputated side) and with their natural arm (on their valid side). CONCLUSIONS: Our novel prosthesis control, based on ANN predicting distal joints from proximal (shoulder or stump) motion plus movement goal information, enables amputees to pick and place objects as well as with their natural arm in a virtual environment. Although much remain to be done to bring this control into a real-life setting, its efficient handling of distal arm movements might judiciously complement alternatives that tend to focus on the control of the hand.

O9.3 Hand-assist robot with a deep learning model for the automatic determination of finger movement direction using surface electromyography: Proof of concept study for clinical applications in patients with stroke

Wataru Kuwahara[1], Tatsuya Mizuguchi[1], Kenya Tanamachi[1], Megumi Okawada[1], Yu Miyawaki[1], Takayuki Kamimoto[1], Yuka Yamada[1], Michiyuki Kawakami[1], Fuminari Kaneko[1]
[1]Department of Rehabilitation of Medicine, Keio University School of Medicine

BACKGROUND AND AIM: Only approximately 20% of stroke patients with upper limb motor paralysis recover their hands to a useful extent. Hence, there is a need to develop devices to replace their hand functions in daily life. We are in the process of developing a hand-assist robot that has been applied to three patents in Japan. We have also designed a prototype of the world's first wearable hand-assist robot. This robot is equipped with a deep learning model to automatically determine the direction of

finger movement using surface electromyography (sEMG). Thus, the automatic discrimination of various sEMG patterns of the paralyzed hand and fingers in patients with stroke is enabled. The sensitivity and positive predictive rate of finger extension of this deep learning model were 97.2 ± 6.7% and 95.6 ± 10.1% for healthy subjects and 57.1 ± 39.5% and 70.5 ± 31.5 % for patients with stroke, respectively. With the hand assist robot prototype designed, its feasibility for clinical application must be evaluated. Therefore, we conducted a proof-of-concept study to determine whether the hand-assist robot can provide functional augmentation to finger function of hemiplegic patients after stroke. METHODS: Five stroke patients participated in this study. The robot consists of sEMG sensors, a control unit with a microcomputer, and a robot that was attached to the subject's hand. A convolutional neural network (CNN) was used as the deep learning model. Functional examinations were performed without the robot prior to the experiment. sEMG tests were performed after the robot was attached. After testing the sEMG signals during the object movement task, we selected two muscles with a clear contrast between the flexor and extensor muscles as target. The deep learning task was performed based on the two target muscles. The sEMG signals were acquired during the object movement task. More than 50 s of data were acquired for each extension and flexion instruction. Deep learning data were transmitted to a microcomputer, and the feasibility of the robot to automatically determine the direction of finger movement based on the sEMG of each patient was validated. The box and block test (BBT) as the primary outcome was performed with the robot. A paired t-test was performed for the BBT with and without the robot. RESULTS: Functional examinations without are shown in the Table. The BBT score with and without the hand-assist robot was 2.0 ± 1.7 and 0.6 ± 1.0, respectively ($p = 0.052$). There were no adverse events. CONCLUSIONS: In severe hemiplegic patients after stroke, the developed hand-assist robot was found to safely assist their hand motor function. In a patient with severe paralysis of the proximal upper limb, it was difficult to provide functional augmentation. It is necessary to verify the effect on patients with mild paralysis and further develop the adaptive algorithm of this hand-robot.

O9.4 Quantifying Changes in Postural Control Related to Robotic Gait Trainer Use from Home Video Data

Sunaina Rangarajan[1], Christa Diot[1], Kelly Larkin-Kaiser[1], Elizabeth Condliffe[1]
[1]University of Calgary

BACKGROUND AND AIM: Head control is a widespread issue for children with significant mobility impairments. The inability to control posture can affect many aspects of life that are necessary for learning and development, such as maintaining eye-contact. There are currently no effective interventions for these children to improve head control. A new robotic gait trainer (the Trexo) improved head control in a case study. This study involves using video data to evaluate changes in head control associated with use of the Trexo robotic gait trainer. METHODS: We asked participants in a prospective trial observing the impacts of Trexo use to film short videos in the frontal plane while using the robotic gait trainer periodically at baseline, after one month of training and after three months. Only those with non-progressive causes of disability were included in this study. Kinematic motion analysis software was used to determine the maximum head angle from vertical in the frontal plane based on frame by frame tracking. To mitigate any error associated with the home video frame of reference, a perspective grid was built on the walker to define horizontal and vertical. Previous research has found children walk with a mean (std) maximum head angle from vertical of 4.10 (12.93) degrees. A Wilcoxon Signed Rank test was used to determine if changes are statistically significant ($\alpha=0.05$). RESULTS: Qualitatively, almost all participants demonstrated poor head control such as extreme neck flexion/extension in the sagittal plane, involuntary movement, as well as the need to rest the head at the end range of motion for extended periods of time. 4 of 10 participants who submitted videos at two or more time points were ineligible for quantitative data analysis as they required the additional support of a cervical collar. The maximum head angle from vertical at the first time point (baseline or 1 month) in the remaining 6 participants ranged from 27-118 degrees, all beyond 1 standard deviation above the mean in typically developing children. After 1-3 months of training, all participants' head control improved by a mean (range) of 15 (4-39) degrees, p=0.028. CONCLUSIONS: All children using a Trexo robotic gait trainer had impairments in head control. Training consistently resulted in improved head control in those whose maximum head angle could be evaluated. These results suggest robotic gait training is a novel rehabilitation strategy to help improve head control in children with mobility impairments.

O9.5 Robot Assisted Gait Training Reduces Sleep Disturbances for Children with Impaired Mobility

Christa Diot[1], Anya Friesen[1], Kelly Larkin-Kaiser[1], Elizabeth Condliffe[1]
[1]*University of Calgary*

BACKGROUND AND AIM: Difficulty sleeping can negatively impact cognitive ability, emotional regulation and physical health. This problem is prevalent in children with impaired mobility and occurs in up to 46% of children with cerebral palsy. Increasing physical activity has been suggested as a non-pharmacological sleep intervention, however, this is hard to achieve in children with impaired mobility. A new technology, the Trexo Home robotic gait trainer (Trexo), aims to aid these children in ambulation. Therefore, the purpose of this study was to explore if sleep improved in children after using the Trexo. METHODS: This prospective observational study included 27 participants with significant motor impairments, age 3-18 years (median 7 (4.5-9)), over the initial 1-2 months of using a Trexo in their home, school and/or community. Participants used the Trexo based on what was meaningful and feasible for their family, and duration was not influenced by the research team. Patient-Reported Outcomes Measurement Information System (PROMIS®) for Sleep Disturbance was reported via parent proxy prior to the onset of Trexo use and completed again after 4-8 weeks of use. Median scores (25th-75th percentiles) are presented with a PROMIS T-score of 56-59 interpreted as mild disturbance, 60-65 as moderate disturbance, and ≥66 as severe sleep disturbance. Change over time was explored using a Wilcoxon Signed-Rank Test (α=0.05). RESULTS: At baseline, sleep disturbance was present in 21/27 participants, with a median score consistent with moderate sleep disturbance, 64.0 (55.6-67.3). After 1-2 months of Trexo use, most participants had a reduction in sleep disturbance with a median change of -3.0 (-7.6 to 0), p=0.0015. CONCLUSIONS: Trexo robotic gait trainer use reduces sleep disturbances in children with impaired mobility as evaluated with a proxy-patient reported outcome measure. This study also confirmed that sleep disturbances are prevalent in children with significant disabilities as evaluated by the PROMIS Sleep Disturbance parent proxy. Future work should explore if improved sleep is augmented with longer periods of gait trainer use and if any benefits persist after ceasing gait trainer use. Larger controlled studies are needed to evaluate if these benefits are reproducible in other users, and to determine optimal durations of usage time to maximize improvements in sleep for children with impaired mobility.

O9.6 Effect of an assistive robotic system's compliance on muscular activity in the leg during caregiving tasks

Maximilian Siebert[1], Anna Wankum[1], Svenja Radek[2], Catherine Disselhorst-Klug[3]

[1]Institute of Applied Medical Engineering, RWTH Aachen, [2]Institute of Health and Nursing Science, MLU Halle-Wittenberg, [3]Institute of Applied Medical Engineering

The clinical use of assistive robotics is inevitable to improve quality of caregiving and to free up personal resources. While robotic support can reduce the physical strain of caregivers during caregiving tasks, the effect on patients' wellbeing and comfort has hardly been investigated so far. Previous work in rehabilitation robotics suggests that the patients' interaction with the robot increases muscular co-activation, which could be a sign of discomfort related to the robotic assistance and might be caused by the difference in compliance between robot and human caregiver. In robotics, compliance refers to the stiffness of a robot when an external force is applied. The aim of this study was to compare muscular activation taking place during nursing tasks with robotic support of different degree of compliance to the muscular activation appearing when support is given by a human caregiver. A lightweight robotic arm (KUKA lbr med) was used to hold a subject's leg for 60 seconds while a caregiver applied a pressure bandage to the subject's foot. The task was performed in 4 different conditions: 1) with low compliance of the robot (LC), 2) with medium compliance (MC), 3) with high compliance (HC) and 4) with a second caregiver holding the leg instead of the robot (CG). The order of the different conditions was randomized. 15 healthy subjects took part in the study. Muscular activation of knee extensors (rectus femoris, vastus lateralis), knee flexors (biceps femoris, semitendinosus, gastrocnemius) and feet extensor (tibialis anterior) were recorded by surface electromyography (sEMG) according to the SENIAM recommendations. For each muscle the resulting sEMG envelope was calculated and the root mean square (RMS) of the envelope was used to evaluate the amount of muscular activation. The results showed a significant decrease in muscular activity of knee extensors when compliance was decreased, while muscular activity was still lower when support was given by a caregiver (CG-condition). Moreover, the muscular activity of most knee flexors increased with lower compliance, but showed significantly higher activation in CG-condition. The feet extensor showed no significant change in activation with robotic compliance, but a significantly higher activation compared to the CG-condition. The higher muscular activity of the knee extensors found during robotic support indicates a voluntary knee extension by the subjects. This suggests a lack of trust in the robotic system being able to support the leg against gravity. However, compared to a human caregiver the robotic system may reduce the subjects' need to actively stabilize the knee joint against rotation, indicated by a smaller muscular co-activation in robotic supported conditions. The results confirm, that assistive robotics negatively affect the muscular activation of patients and thus has impact on their comfort during nursing tasks. This should be taken into account for the further design of robotic devices.

Oral 10 – Neuromechanics and Sports Sciences and Motor Performance

O10.1 No change in beta intermuscular coherence in agonist-antagonist leg muscle pairs after a two-day balance intervention despite improvements in balance performance

Lisanne Bakker[1], Claudine Lamoth[1], Tibor Hortobágyi[1]
[1]University Medical Center Groningen

BACKGROUND AND AIM: The ability to maintain postural equilibrium while standing on a narrow or unstable surface, i.e., maintaining dynamic balance is a motor skill. Healthy individuals can learn an unfamiliar dynamic balance skill very rapidly, in 20-30 minutes. Acquiring a dynamic balance skill is associated with neural adaptations. Intermuscular coherence in the beta band is known to index subcortical and cortical sources in motor skill learning. However, the little we know about the neural mechanisms and time course of dynamic balance skill learning are controversial, as there have been reports of decrease, no change, or increase in specific metrics of neural adaptations to dynamic balance skill learning. The purpose of this study was to examine the effects of two balance training sessions on balance skill acquisition and retention and to examine the underlying neural plasticity by intermuscular coherence. METHODS: Healthy younger adults (n=13, mean (±SD) age: 22.7 (2.4) years, height:1.74 (0.09) m, weight:72.32 (13.45) kg) were randomly assigned to a balance intervention (BAL) on an unstable board (Miniboard, Sensamove®, Groessen, NL) or seated rest (CON). Before and immediately after the first and second intervention day as well as ~7 days after the second intervention day, balance performance was assessed. While performing the balance task, electromyography activity of 7 muscles in each leg were recorded. Intermuscular coherence in the beta band between 8 agonist-antagonist muscle pairs was calculated to examine potential underlying mechanisms of learning a dynamic balance skill. RESULTS:Preliminary and exploratory analyses revealed that BAL improved time in balance on the unstable board by 61% (effect size, d=0.76, p<0.05) compared to baseline after two intervention days, while CON improved by 21% (d=0.25, p<0.05) compared to baseline. The acquired skill was retained after a ~7 day-long no-training period. Practicing a dynamic balance skill on an unstable board on 2 days did not affect beta band intermuscular coherence between agonist and agonist-antagonist muscle pairs (all p>0.05). CONCLUSIONS: The exploratory analyses of the preliminary data in this study reveal an improvement in balance performance without an adaptation in the intermuscular coherence in the beta band assessed in agonist-antagonist muscle pairs following a two-day balance intervention. The presentation will include analyses of an expanded database.

O10.2 Acute effects of the bench press exercise inclination on the neuromuscular and structural parameters of the clavicular and sternocostal regions of the pectoralis major muscle

José Albarello[1], Hélio Cabral[2], Bruno Leitão[1], Tea Lulic-Kuryllo[3], Liliam Oliveira[1], Thiago Matta[1]
[1]Federal University of Rio de Janeiro, [2]University of Birmingham, [3]Università degli Studi di Brescia

BACKGROUND AND AIM: Recent evidence confirms a selective activation of the pectoralis major (PM) muscle during the inclined bench press exercise, with greater activity quantified for the clavicular region than the sternocostal region [1,2]. Whether the acute muscle architecture changes after this exercise are also non-uniformly distributed within the PM remains an open issue. Therefore, this study investigated the acute effects of the flat bench press (FBP) and inclined bench press (IBP) exercises on the muscle activity and variations in the cross-sectional area (CSA) of the clavicular and sternocostal PM regions. METHODS: Fourteen men with previous resistance training experience performed four sets of the FBP and IBP with a load of 60% of the one-repetition maximum. Before and immediately after the exercises, panoramic ultrasound images were collected transversely to the PM fibers, with the transducer following the midclavicular line up to the lower edge of the PM [3]. During the exercises, bipolar surface electromyograms (EMGs) were acquired from the clavicular and sternocostal PM regions. The variations in the CSA of each PM region were calculated as the difference between the pre- and post-exercise value normalized by the pre-exercise value. The magnitude of normalized muscle activity for each PM region was estimated from the root mean square (RMS) amplitude of surface EMGs and averaged across concentric repetitions, separately for each set. Two-way repeated-measures ANOVAs were used to compare the effect of the two bench press inclinations and the two PM regions on the CSA variation and normalized RMS (separately for each set). Tukey's post-hoc test was used for paired comparisons whenever the main effects were observed. RESULTS: For all sets of the IBP, the normalized RMS amplitude quantified for the clavicular region was greater (32-35%) than the sternocostal region (panel A; P < 0.001 for all cases). During the FBP, the normalized sternocostal region

RMS amplitudes were significantly greater (25-35%) than the clavicular region across all exercise sets (panel A; $P < 0.001$ for all cases). Similar results were observed for the architectural parameter, with greater (~11%) CSA variations quantified in the clavicular than the sternocostal region after the IBP (panel B; $P < 0.001$). Conversely, the sternocostal region had ~5% greater CSA variations than the clavicular region after FBP (panel B; $P = 0.046$). CONCLUSIONS: Our results revealed that the activation pattern and the acute variations in the CSA are non-uniformly distributed within the PM, depending on the bench press inclination. These findings indicate that variations in the inclination of the bench press exercise can be used to emphasize different regions of the PM muscle. REFERENCES: [1] Coratella et al. 2020; Eur J Sport Sci 20(5): 571-79. [2] Cabral et al. 2021; Scand J Med Sci Sports 00: 1-10. [3] Mangine et al. 2015; Physiological Reports 3(8): e12472.

O10.3 The effects of subclinical neck pain on cerebellar processing as measured by the cervico-ocular and vestibulo-ocular reflexes

Devonte Campbell[1], Paul Yielder[1], Bernadette Murphy[1], James Burkitt[2], Praveen Sanmuganathan[1], Rufeyda Cosgun[1], Laura Ruberto[1], Akash Toor[1]
[1]Ontario Tech University, [2]McMaster University

Subclinical neck pain (SCNP) is defined as recurrent episodes of mild-to-moderate neck pain that has not yet received treatment. Its recurrent nature allows neurophysiological measures to be collected on pain free days to avoid the confounding effects of pain on movement patterns, and prior literature has demonstrated neurophysiological alterations in cerebellar processing in individuals with SCNP. To date no direct measures of cerebellar function have been utilized to assess changes within the cerebellum in individuals with SCNP. Two of these direct measures are known as the cervico-ocular and vestibulo-ocular reflexes (COR & VOR) which are oculomotor reflexes that act to keep images stable on the retina in response to trunk and head movements. These two reflexes are directly controlled by the cerebellum. Thus, due to this altered cerebellar processing, it is possible that individuals with SCNP may experience alterations in both their COR and VOR as well. This study aims to investigate the relationship between SCNP and the cerebellum by measuring changes in COR gain and VOR gain adaptation in individuals with SCNP. METHODS: 10 right-hand dominant participants with and without SCNP performed two eye-tracking tasks. 5 participants with neck pain were allocated to the SCNP group and 5 participants without neck pain were allocated to the healthy control group. In the first task, participants were seated within a motorized chair and fitted with an eye-tracking device. They were instructed to stare at a visual target projected on a monitor 3 meters away from them. Once the target appeared on the screen, the motorized chair began a series of oscillations at a frequency of 0.04 Hz, with an amplitude of 5º, for 120 seconds. Participants completed 10 trials, with each trial lasting two minutes. In the second task, participants were seated 90 cm away from a monitor and were instructed to make active head rotations while tracking a target projected on the screen in-front of them. Participants performed 390 trials divided into 13 blocks (pre-adaptation, 10 adaptation, & 2 post-adaptation blocks) in which the target would move at different speeds during each block. PRELIMINARY RESULTS: On average, the SCNP group demonstrated a higher COR gain (Q1 = 0.194, Q3 = 0.503, $\bar{x}$ = 0.3513) compared to the healthy control group (Q1 = 0.129, Q3 = 2.01, $\bar{x}$ = 0.1581). While the healthy control group demonstrated a greater percent change, in VOR gain, from the pre-adaptation block to the 10th adaptation block ($\bar{x}$ = 14.5%) compared to the SCNP group ($\bar{x}$ = 4.5%). On average, the SCNP group also demonstrate higher VOR gain values ($\bar{x}$ =1.097) than the healthy control group ($\bar{x}$ = 1.193), during the entirety of the protocol. DISCUSSION: These preliminary results suggest that individuals with

SCNP have a disrupted COR and VOR compared to individuals without neck pain. This suggests that the altered neural processing observed in past studies is reflected in a direct measure of cerebellar processing and function. Additionally, this upregulation of the COR may be a compensatory action in response to disruptions in the VOR.

O10.4 Mechanoreceptors Become More Sensitive To Loading When Skin Temperature Is Elevated

Erika Howe[1], Michael Apollinaro[1], Joanna Reeves[2], Christopher Nester[3], Leah Bent[1]
[1]University of Guelph, [2]University of Bath, [3]University of Salford

Skin mechanoreceptor input from the foot sole is critical for balance and gait¹. Cooling has been used to mimic the decline of foot sole sensation caused by aging and diabetic neuropathy and hinders balance and alters gait patterns². Single afferent recordings have shown that cooling causes unique decreases in firing rate for each class of mechanoreceptor which was speculated to be related to a decrease in skin blood flow³. In contrast, heating causes a robust skin vasodilation and improves vibratory detection thresholds⁴. Whether this improved sensitivity is due to changes in mechanoreceptor firing is unknown. The aim of our work was to establish the effect of heat on firing patterns of single cutaneous afferents in response to loading or vibration of the foot sole. It was hypothesized that all afferents would increase firing rates with heat. Single afferents from the tibial nerve were recorded using microneurography. Afferents were classified into receptor type, and sensitivity thresholds and receptive field (RF) sizes were established⁵. Three ramp and hold indentations, normalized to standing regional force distributions, were applied over the RF using a 1 cm2 probe. In addition, some units were vibrated at either 30 or 150 Hz using a mini shaker (Bruel & Kjaer 4810). Vibration bursts were 3s with increasing amplitudes. The RF was heated to 38-42°C with a reusable heating pad and the loading or vibration was repeated. Dynamic index of loading was quantified by peak3; the average of the three max instantaneous frequency values during the ramp. Static sensitivity was evaluated using a 1s mean firing rate during force plateaus. Activation threshold was recorded as the smallest amplitude that activated a unit during vibration. The 28 recordings that remained stable for the entire duration of the protocol were identified as fast-adapting (FA) or slowly adapting (SA) type I or II5 (FAI n=7, FAII n=4, SAI n=6, SAII n=11). Heating increased skin temperature by 9.5±2.4°C (p=0.002). Upon heating, SAIs significantly increased static rates (p=0.05) and SAIIs significantly increased both peak3 (p=0.031) and static rates (p=0.02). To date, heating FAI (n=5) revealed a modest increase in peak3 when loaded (p<0.09) but unexpectedly required a greater amplitude to activate FAI receptors when vibrated at 30 Hz (n=2). More FA data is required to draw firm conclusions. Together, these data show a link between heat and afferent firing, which may support a relationship between skin blood flow and sensory feedback. More importantly, heat significantly increases SA receptor sensitivity; SAII's increased dynamic sensitivity could compensate for the loss of FA receptors in aging and diabetes⁶. Heating could be a therapeutic application for falls prevention. 1)Nurse & Nigg 2001 2)Eils et al 2004 3)Lowrey et al 2013 4)Schlee et al 2009 5)Johansson 1982 6)Pare et al 2007

O10.5 Acute Effects of Blood Flow Restriction on Activation of the Vastus Lateralis Muscle

Eduard Kurz[1], Thomas Bartels[2], Stefan Pröger[2], Oliver Röhrle[3], Karl-Stefan Delank[1], René Schwesig[1], Leonardo Gizzi[3]
[1]Martin-Luther-University Halle-Wittenberg, [2]Sports Clinic Halle, [3]University of Stuttgart

BACKGROUND AND AIM: Blood flow restriction (BFR) training is increasingly used in post-surgery rehabilitation settings. Through the temporary compression of soft tissues and blood vessels occlusion, low-load resistance training regimes elicit comparable adaptation effects to traditional heavy-load resistance training. Consequently, BFR training is a valuable exercise modality to slow down deconditioning early after injury, especially in professional sports. This study primarily aimed at examining acute effects of low-intensity muscle contractions with BFR on vastus lateralis (VL) muscle fiber conduction velocity (CV). METHODS: Eight sub-elite male handball players (mean age 25, standard deviation (SD) 4 years) were examined at their dominant lower limb. Participants performed seven isometric ramp contractions at 30% maximum voluntary torque for 24 seconds after three familiarization contractions. BFR was provided for approximately five minutes before the fourth ramp at 80% (154 (SD 5) mmHg) of the individual occlusion pressure. Activity of the VL was recorded in monopolar mode (EMG-USB2+, OT Bioelettronica, Italy, sampling rate: 2048/s) using a linear electrode array (ELSCH004, Spes Medica, Italy) concurrently with the isometric force (SM-2000N, Forza, gain: 200). From the raw signals, muscle fiber conduction velocity (CV), root mean square (RMS), and median frequency (MDF) from the power density spectrum were calculated. Percentage changes were compared to the averaged values (first three ramps) before BFR. Effect sizes (d) and linear relationships were estimated using the one-sample t and Pearson's r statistics, respectively. RESULTS: The participants showed on average a CV of 4.96 m/s (SD 0.74), an RMS of 0.29 V (SD 0.07) and a MDF of 57 Hz (SD 8) before the BFR. During the BFR, the CV increased by 5.3% (SD 3.1, $d = 1.6$). The CV dropped after the BFR but remained increased ($d > 0.8$). The RMS increased by 18% (SD 13, $d = 1.1$) during, and declined below the baseline five minutes after, the BFR ($d < -0.45$). Only small changes were identified for the MDF (< 6%, $d = 0.24$) during the BFR, which consistently increased after release of the BFR ($0.8 < d < 2.0$). CONCLUSION: These preliminary findings suggest a redistribution of the motor units involved during the submaximal blood flow occlusion. Both decreased shares of oxygen-dependent lower-threshold motor units and a compensatory hyperexcitability of high-threshold motor units may contribute to the observed changes in muscle activation.

O10.6 Analyzing muscular activation in response to effort matched low-intensity blood-flow restriction and moderate-intensity exercise protocol

Jinghui Yang[1], Rory O'Keeffe[1], Sarmad Mehrdad[1], Seyed Shirazi[1], S.Farokh Atashzar[1], Smita Rao[1]
[1]*New York University*

BACKGROUND AND AIM: Muscle activation is a key factor driving adaptation with resistance training. Evidence has shown that low-intensity blood flow restriction (BFR) resistance training (RT) induces comparable gains in muscle adaptation compared to moderate to high-intensity RT. However, limited studies have examined muscle activation in response to BFR RT and moderate intensity (MI) RT. METHODS: 12 healthy subjects (27±3 yrs, 23±3 kg/m2, 5 F) participated in this study. A repeated measures design with counterbalanced RT conditions (MI or BFR) was applied. All subjects completed two visits. At each visit, the dominant leg one-repetition maximum (1RM) was determined on a leg press machine after standardized warm-up. For MI, subjects performed a unilateral leg press with the dominant leg at 50% 1RM. For BFR, a 20-cm width cuff was placed at the proximal part of the dominant thigh during exercise. Subjects performed the leg press at 30% 1RM with the cuff inflated to 60% limb occlusion pressure. Subjects performed four sets of RT in each visit under a protocol of 30-15-15 repetitions at the first 3 sets and exercised to failure for the last set. There was a 30-second rest between each set. A metronome was applied to provide a consistent rate of contraction: one second for concentric contraction (leg extension) and one second for eccentric contraction (leg flexion). The exertion level (Rating of Perceived Exertion, RPE) at the end of each set was collected. The total training volume was calculated as repetitions* load. The rectus femoris muscle (RF) activation during exercise was acquired using surface electromyography (sEMG) (Trigno, Delsys Inc, USA). The sEMG electrodes placement followed the SENIAM guidance. The raw data were filtered (fourth-order Butterworth, band-pass 15-450 Hz), and the root mean square (RMS) was calculated during the concentric part of the leg press. The concentric phase was determined by an electrogoniometer, which was fixed on the side of the exercise knee. RMS amplitudes of the first and last three repetitions of each visit were averaged, and the value of the last three reps was normalized to the first three reps of the first set. The change in RMS was expressed as the percentage difference between the beginning and end of the exercise. Paired t-tests (α=0.05) were applied to compare RPE, training volume, and RMS. RESULTS: Similar exertion levels (17±1.44 vs. 17±2.32, BFR and MI, respectively, p=0.450) and greater training volume with MI (1778±1663 vs. 3264±2408 lbs., BFR and MI, respectively, p=.003) were observed. Similar RMS changes were noted (0.69±0.98% vs 0.88±1.09%, BFR and MI, respectively, p=0.593). CONCLUSION: Contrary to our hypotheses, no statistical differences in RF RMS amplitude were noted with low-intensity BFR (30% 1RM, 60% LOP) versus MI (50%1RM) RT. Future studies are indicated to examine power spectral density and muscle activation in other synergists such as the Vastus Lateralis and Gluteus maximus.

O10.7 Shoulder-trunk coordination and sequencing during slap shots in ice hockey players

Shawn Robbins[1], Philippe Renaud[1], Neil MacInnis[2], David Pearsall[1]
[1]McGill University, [2]Curv Health

BACKGROUND AND AIM: In ice hockey, slap shots produce the fastest puck speeds of all shot types. Research evaluating slap shot performance has focused on stick properties or player characteristics. There has been limited research examining optimal body kinematics during shooting on real ice, and comparing these variables between skill levels. The objective was to compare shoulder-trunk inter-joint coordination and joint sequencing between high and low calibre ice hockey players when completing a slap shot on the ice surface. METHODS: High (n=10; mean age 26 years) and low (n=9; mean age 26 years) calibre male hockey players were recruited. Reflective markers were placed on the players, stick, and puck. A 14 camera Vicon motion capture system sampled at 240 Hz captured marker data. Participants completed ten skating slap shot trials where they shot 9.25 m from the net on real ice. Players used the same stick type (Nexus 1N, 87 flex, Bauer Ltd). The slap shot was divided into backswing and downswing. Peak puck speed was calculated. Trunk and shoulder angles were calculated using Euler YXZ and ZYZ sequences, respectively. Both lead and trail shoulders were considered (e.g., right shoulder is trail side for right handed shooters). Inter-joint coordination between the shoulder-trunk was determined using continuous relative phase (CRP), and both magnitude and inter-trial variability measures were calculated. To determine sequencing, the norm of the joint angular velocity was calculated for the trunk and shoulders. Then, peak velocity in relation to puck release was determined. Mann-Whitney U tests examined differences in puck speed, inter-joint coordination magnitude and variability, and sequencing between high and low calibre players. RESULTS: High calibre players produced faster puck speeds (mean difference=2.94 m/s), although this was not statistically significant (p=0.105). For shoulder-elevation plane/trunk rotation (p=0.050) and shoulder-elevation/trunk rotation (p=0.028) inter-joint coordination on the trail shoulder, high calibre players had greater CRP magnitude values than low calibre players. Thus, high calibre players were more out-of-phase, specifically during the backswing phase (Figure 1). There were no differences in lead shoulder/trunk CRP magnitude and CRP inter-trial variability. For sequencing, peak trunk angular velocity occurred earlier in relation to peak shoulder (trail side) angular velocity (p=0.038) for high calibre players. CONCLUSIONS: High calibre players were more out-phase for shoulder-trunk angles during the backswing on the trail shoulder, potentially allowing them to adapt more easily to varying shot environments. High calibre players also had earlier onset of peak angular velocity of the trunk relative to the trail shoulder. This proximal to distal sequence might help them produce faster puck speeds, similar to a golf swing.

Oral 11 – Biomechanics and Wearable Sensors & IoT

O11.1 Feature Selection Techniques on Biomechanical Parameters from Pressure Mats for Identifying Elderly Fallers

Ashirbad Pradhan[1], Karansinh Padhiar[1], Victoria Chester[2]
[1]University of New Brunswick Fredericton, [2]University of New Brunswick

Background: Accidental falls are one of the leading causes of death among older adults [1]. An individual with a history of falls is associated with an increased risk of a future fall [2]. Identifying a prospective faller would allow earlier interventions for fall risk reduction [3]. Pressure mats are portable and provide accurate and reliable balance and gait assessment solutions in the clinical setting. Previous studies have utilized pressure mats for classifying older adult fallers. The biomechanical parameters from the pressure mats were used for retrospectively identifying pathological gait and balance in elderly fallers [4]. In this regard, dimensionality reduction of the biomechanical parameters is important to remove redundancy and improve elderly faller classification. The purpose of this study was to analyse the performance of various dimensionality reduction techniques on pressure mat data for improving the classification of older adult fallers and non-fallers. Method: A database of 99 participants was used for this study, including 58 non-fallers (NF) and 41 fallers (F) who performed balance (standing with eyes open and eyes closed) and gait on a walkway with pressure mats [5]. A total of 49 biomechanical parameters, including the components of the center of pressure (COP), COP displacement/velocity data and plantar pressure (PP) data (peak contact pressure, mean pressure, and force/pressure time integrals), were selected. Dimensionality reduction techniques, such as feature selection to select the most important features and feature extraction for data transformation, were used. The reduced feature space served as input to a linear-kernel support vector machine classifier and its performance was tuned using hyper-parameter optimization. Finally, the model was validated using 5 iterations of 5-fold stratified cross-validation and the mean classification accuracies were reported (Table 1). Results and Conclusion: Using the full feature set for combined balance and gait tasks resulted in lower classification accuracy (71.11%). Applying bi-directional feature selection resulted in a significant increase in accuracy (85.58%). Additionally, it was found that the COP parameters of gait tasks had the largest ANOVA F-score values, suggesting they contributed the most. Feature extraction using linear discriminant analysis (LDA) gave the highest accuracy score of 94%. Therefore, biomechanical parameters obtained from pressure mat data from balance and gait tasks, followed by appropriate dimensionality reduction, can provide accurate and reliable identification of fallers in a clinical setting.
[1] Delbaere, K. et al, J Amer Geri Soc, 58(9), 1679-1685, 2010. [2] M. E. Tinetti et al, Jama, vol. 303 (3), pp. 258-266, 2010. [3] L.V.V. Moncada et al, Family Physician, vol. 96 (4), pp. 240-247, 2017. [4] Pradhan et al, CMBBE, pp. 339-353, 2019. [5] RS Oladi Ghadikolaei, Master's dissertation, University of New Brunswick, 2018.

O11.2 Changing neck posture during violin playing with an ergonomic chinrest used with and without a shoulder rest. A feasibility study.

Stephanie Mann[1], Carsten Juhl[1], Helene Paarup[1], Karen Søgaard[1]
[1]*University of Southern Denmark*

Introduction: A violin is fixed in shape and size, and this requires the musician to adapt to the instrument often with a rotated and lateral neck position. Potentially, this can lead to neck and shoulder pain as commonly reported by violinists (1). To accommodate a neutral neck position, a search for an ergonomic chinrest (EC) was conducted and resulted in the identification of just one fully adjustable chinrest (Kréddle). The overall aim of this study was to examine the feasibility of using the EC with (EC+) and without (EC-) a shoulder rest and if it would lead to a change in neck position during violin playing compared to playing as usual. Methods: A two-week familiarization period was given to violinists included with skills to play a classical repertoire required at Danish conservatories. Subsequently, a test day was scheduled for the neck measurements. Neck position was measured with ViMove sensors attached on a headband at the base of the skull and at the top of T3. The violinist played an excerpt of Mozart's Violin Concerto no. 5 . Evaluation was done in accordance with the Standard Evaluation of Static Working postures from ISO defining two categories for the lateral flexion neck angle as neutral (-10 to 10 degrees) and awkward (>-10 degees or >10 degrees). The time spent in an awkward lateral neck posture either to the left or right side >10 degrees was calculated in percentage of the total time spent in lateral neck postures. Adherence data during the familiarization period was evaluated by a diary and compliance was evaluated based on percentage of total daily playing time with EC- and EC+. Full compliance was a minimum of 50% for both settings. Performance and comfort were scored from 0 to100), with a higher score indicating lower performance or comfort. Results: Six violinists participated (age 21-55). Playing with EC+, EC- and usual setting resulted in median time in an awkward neck position of 8.5 % (IQR;4), 8.5% (IQR;13) and 15% (IQR;26) respectively. Median for adherence to play all 14 days was 89% (64-100%) for EC- and 100% for EC+. Compliance for EC- was <50% for two violinists and median 90.5%. Median performance score for EC- was 58.3 points and for EC+. 4.2 points, while median comfort score was 40 for EC- and 30 for EC+. Conclusion: Both EC+ and EC- changed the neck positions to a more neutral posture compared to their usual playing setting. However, EC- is not feasible since two out of six violinists didn't meet the criterion for minimum playing time for EC- and also performance and comfort were lower compared with EC+. These results have informed a larger study using EMG and 3D analysis of neck movements to further investigate the potential of EC+ to minimize risk of neck and shoulder pain. 1) Kok, L.M., Huisstede, B.M.A., Voorn, V.M.A., Schoones, J.W., Nelissen, R.G.H.H., 2016. The occurrence of musculoskeletal complaints among professional musicians: a systematic review. Int. Arch. Occup. Environ. Health 89 (3), 373-396.

O11.3 Coordination between synergistic muscles is highly variable within and between individuals in a tightly constrained isometric trunk extension task

Louise Tier[1], Sauro Salomoni[1], Francois Hug[2], Manuela Besomi[1], Paul Hodges[1]
[1]*University of Queensland,* [2]*Institut Universitaire de France (IUF), Paris, France/ LAMHESS, Universite Côte d'Azur, Nice, France*

BACKGROUND AND AIM: The redundancy of the trunk muscles means that multiple strategies are available to coordinate activity of the synergistic back muscles (with differing anatomy and moment arms) to perform a single motor task. This study aimed to investigate whether the coordination between synergist back muscles in a tightly constrained trunk extension task differed between participants and between repetitions within a participant, and whether this coordination could be modified by a brief exposure to feedback of activation of one synergist muscle. METHODS: Nine healthy subjects were positioned in side-lying, with the lower body firmly stabilised, and performed ramped isometric trunk extension efforts against a bar placed at the level of T12. Force was increased from 0 to 30% of maximum voluntary contraction (MVC) over 30s for 2 repetitions. Trials were performed in three separate conditions. The first was performed in an unconditioned state in which the task was performed with force feedback and no feedback of muscle activity (Natural). In the other two conditions, the trials with force feedback were preceded by two repetitions with feedback of electromyography (EMG) of either superficial multifidus (After SM) or deep multifidus (After DM) muscles. EMG was recorded using intramuscular electrodes inserted into SM and DM at the level of L5, and longissimus (LG) at L2. RESULTS: In the Natural condition, group level analysis showed greater EMG amplitude of SM than the other muscles, an incremental increase in EMG with force, and a constant relationship between muscles over force intensities. Greater activation of SM was not consistently reflected in data for individual participant. Notably, the muscle with greatest activity differed between participants (between SM and DM) and the relationship between muscles changed as a function of force. Within participants, the contribution of each muscle to total EMG also differed between repetitions to a variable extent. Despite no change in task constraints, after brief exposure to EMG of DM or SM, the coordination between muscles was changed by reduced activation of the muscles that were not provided as feedback in the preceding contractions. CONCLUSIONS: The results of this study showed that although group data imply simple and consistent coordination between muscles, when data are examined for individual participants, there is substantial within- and between-participant variation in coordination, even in a tightly constrained single plane task. Brief exposure to feedback of a muscle can induce changes in coordination.

O11.4 Anatomy and biomechanics of gastrocnemius medialis and lateralis subtendons in different horizontal foot positions

Marion Crouzier[1], Félix Dandois[1], Stijn Bogaerts[2], Lennart Scheys[2], Benedicte Vanwanseele[1]
[1]KU Leuven, [2]University Hospitals Leuven

Background and aim. The gastrocnemius muscle is composed of the medial (GM) and lateral (GL) heads that each attach to different subparts of the Achilles tendon to form their respective subtendons. The relative activation of GM compared to GL during submaximal plantarflexion was shown to depend on the position of the foot in the horizontal plane, i.e. whether the foot is internally (toes-in) or externally (toes-out) rotated. Specifically, performing a submaximal plantarflexion with the toes-in increases GL activation and decreases GM activation compared with toes-out. It is unknow if this change in gastrocnemii activations generates different lengthening of their respective subtendons and impacts the motions within the Achilles tendon distally. The aim of the current study was to investigate whether foot rotation affects Achilles subtendons length (at rest) and Achilles subtendons lengthening and distal motions in the Achilles tendon (during submaximal plantarflexion). Methods. Twenty healthy subjects (12 females and 8 males) participated in the study (26 ± 3 yr). Participants realized isometric sustained contractions while three-dimension ultrasound images were taken to capture subtendons lengths. Participants additionally performed ramped isometric contractions while ultrasound images were recorded at the distal end of their Achilles tendon in the sagittal plane. A speckle tracking algorithm was applied to the images to measure between-layers motions within the Achilles tendon. Both tasks (sustained and ramped contractions) were conducted with toes-in and out, and at 20 and 40% of the maximal voluntary torque level. Results. At rest, the two subtendons were shorter with toes-out than toes-in, but this difference only reached significance for the GM (toes-out: 193.4 ± 24.4; mm toes-in: 197.9 ± 24.8; $p < 0.01$). The GM subtendon lengthened more in toes-out, compared to the GL, and vice versa (all $p < 0.01$), regardless the intensity of contraction. The relative motions within Achilles tendon (deep minus superficial layers displacements) were not statistically different between foot positions but tended to be reduced with toes-in ($p = 0.08$). Conclusion. We provided evidence that, at rest, the anatomy of the gastrocnemii subtendons is affected by foot rotation. The Achilles tendon is twisted, and its medial fibers run posteriorly and laterally, from proximal to distal. Hence, turning the toes-out could "unfold" the Achilles tendon, which would explain the longer subtendons lengths with toes-in. It is possible that the resulting higher elongation of the GM affects motor control differently between foot rotations, for example by changing afferences to the nervous system. During contraction, the Achilles tendon biomechanics is affected at least in its proximal motions. Such observation may be relevant in a context of Achilles tendinopathy, where gastrocnemii activations and Achilles tendon biomechanics are altered.

O11.5 Tongue HD-sEMG: design and test of an electrode grid for intraoral recordings

Alberto Botter[1], Federica Vitali[1], Giacinto Luigi Cerone[1]
[1]Politecnico di Torino

BACKGROUND AND AIM. Tongue motor function is essential in numerous daily activities and may be impaired by several factors, from pathologies affecting the central nervous system to anatomical alterations following traumatic events or cancer surgery. An adequate electrophysiological assessment of this muscle complex could contribute to the rehabilitation and follow-up of specific functional tasks, as well as to the diagnosis of neuromuscular diseases (e.g. through the identification of fasciculation potentials [1]). The assessment of tongue muscle activity is chiefly performed with needle EMG. To date, surface EMG is rarely used because of the difficulty in achieving a stable contact between surface electrodes and the tongue. However, surface EMG may be preferable to intramuscular recordings, not only for its non-invasiveness, but also for the possibility to obtain a more representative description of the muscular activity, resulting from the activation of several muscle compartments with different fiber arrangements [2]. The aim of this work was to develop an electrode grid for intraoral, high-density surface EMG (HD-sEMG) detection from the tongue. The following project specifications were considered: a system with a few tens of electrodes distributed over the entire surface of the tongue, allowing the subject to perform natural tongue movements while ensuring adequate mechanical and electrical stability for at least 20 minutes. METHODS. We developed a grid of 4 x 8 electrodes deposited over a thin (8µm) polyurethane membrane. Each column of electrodes was a pre-printed flexible circuit (2mm width) housing eight electrodes. The height of individual electrodes was 300µm to improve the stability of the electrode-tongue contact. The polyurethane membrane was secured to the tongue with surgical glue, using a positioning tool specifically designed for this purpose. The testing protocol was carried out on 10 healthy subjects and included 20 minutes of functional tasks such as the pronunciation of alphabet letters, swallowing, and movements aimed at activating specific areas of the tongue. Electrical stability of contact was assessed by measuring electrode-tongue impedances (f=50Hz) before and after the tasks. RESULTS. Impedance modules showed no significant changes in the per-post comparison (58±46 kΩ vs. 67±58 kΩ at 50Hz). Contact stability was confirmed by the high quality of the signals that allowed to quantify spatiotemporal characteristics of EMG activation during the different tasks. The analysis of the spatial distribution of individual MUAPs decomposed from HD-sEMG showed that they were confined in relatively small areas (10mm2 - 160mm2). A variety of different spatiotemporal MUAP patterns, likely due to the presence of different muscle compartments with different fiber orientations, was observed. CONCLUSIONS. Our results demonstrate that the developed electrode grid enables HD-sEMG acquisitions from the tongue during functional tasks, thus opening new possibilities in tongue muscle assessment both at global and single motor unit level. 1. de Carvalho M et al. 2008. Clin Neurophysiol. 2. Sanders and Mu 2013. The Anatomical Record.

O11.6 Development and characterization of a wireless Body Sensor Network for integrated EEG and HD-sEMG acquisitions

Giacinto Luigi Cerone[1], Alessandra Giangrande[2], Marco Ghislieri[1], Marco Gazzoni[1], Harri Piitulainen[3], Alberto Botter[1]
[1]Politecnico di Torino, [2]Politecnico di Torino and University of Jyväskylä, [3]University of Jyväskylä

BACKGROUND AND AIM: The human brain plans the motor execution through sensorimotor integration according to external inputs. Temporospectral analyses, (e.g. cortex-muscle coherence [1]), are common methods to investigate the neuronal mechanisms underlying the central control of muscle activation. The assessment of sensorimotor integration requires synchronous acquisition of several central and peripheral physiological signals, such as, EEG, sEMG, and kinematics. However, technological bottlenecks limit their concurrent application in naturalistic conditions outside the research lab. Wireless devices for electrophysiological or biomechanical signal detection have been proposed [2] and are available on the market. Nevertheless, they might be prone to power line interference and movement artifacts and they typically do not allow to readily integrate the acquisition of mixed signals (EMG, EEG, kinematics, etc.) that is a prerequisite to comprehensively investigate the sensorimotor integration. This leads to complex and unpractical setups, often limiting the conditions in which data acquisition can be performed. The aim of this work was to design and develop a wireless Body Sensor Network (wBSN) allowing the synchronous acquisition of cortical (EEG) and muscular (HD-sEMG - High Density sEMG) activity for the assessment of the sensory evoked cortical responses and corticospinal coupling. METHODS: The proposed system [3,4] implements a client-server wBSN (Fig.a) composed of a set of 32-channels Sensor Units (SU, clients) for the simultaneous acquisition of HD-sEMG and EEG signals and of one device (server) for signal visualization and storage. Each SU performs the conditioning, sampling and transmission of the input signals to the receiver (mobile device, or PC), through a Wi-Fi router, for visualization and storage. A general-purpose synchronization system composed of transmitting and receiving units allows the synchronization of signals detected by different SUs and the integration of third-party devices (Fig.b) used to either provide stimuli (e.g., auditory, visual, tactile, etc.), or to acquire other variables (e.g., force, kinematics, etc.). An in-depth characterization of the system and a head-to-head comparison with a wired benchmark EEG device were performed on ten subjects in several experimental contexts, including the detection of event-related potentials and cortex-muscle coherence during sensory stimulations and isometric contraction task. RESULTS AND CONCLUSIONS: The system characterization, described in [4], confirmed the agreement with the project specifications and the experimental performances demonstrated the high quality of collected signals (e.g. no significant differences from the RMS of powerline interference at 48 Hz - 52 Hz ($p = 0.28$ - Wilcoxon rank-sum statistical test)). The developed wBSN, being modular and miniaturized, represents an enabling technology to extend the investigation of the brain-body interactions during both static and naturalistic tasks. 1. E. Lattari et al. (2010), Rev. Neurol. 2. Y. Xie et al. (2020), IEEE Sens. J. 3. Cerone et al. (2019), IEEE TBME. 4. Cerone et al. (2022), IEEE TNSRE.

Oral 12 - Pain

O12.1 Subclinical neck pain leads to Differential Changes in Early and Middle-latency Somatosensory Evoked Potentials and Motor Performance in response to a novel force matching tracking task

Ushani Ambalavanar[1], Heather McCracken[1], Hailey Tabbert[1], Paul Yielder[1], Bernadette Murphy[1]
[1]Ontario Tech University

BACKGROUND AND AIM: Altered afferent input from neck dysfunction (i.e. pain, joint dysfunction, postural stress, and/or fatigue) alters central, cortical and/or cerebellar processing of sensory input. Subclinical neck pain (SCNP) refers to mild-to-moderate recurrent neck pain where individuals experience pain-free days, enabling neuromechanical testing to occur unconfounded by acute pain. Past work indicates that SCNP results in impaired upper limb proprioception and motor control, as well as maladaptive neuroplasticity affecting excitability and/or upregulation of synaptic connectivity between the sensorimotor cortex and the cerebellum, and impairing the ability to learn novel motor typing and/or tracing tasks. Given these deficits pertaining to the central processing of somatosensory information and proprioceptive awareness, it is plausible that the ability to produce and modulate forces could also be impaired in those with SCNP. The purpose of this study was to compare changes in somatosensory evoked potential (SEP) peak amplitudes and motor performance accuracy between SCNP and healthy controls for a right-thumb force matching task. METHODS: Five healthy control (2 females, age: 20.2 ± 1.3 years) and five SCNP (2 females, age: 20.4 ± 2.3 years) right-handed, participants were administered electrical stimulation at 2.47 Hz and 4.98Hz (1000 sweeps each) over the right-median nerve, to assess differential changes in the amplitude of short and middle-latency SEP peaks following motor acquisition of a force matching tracking task (FMTT). Participants matched a series of force traces calibrated to their right thumb strength using their right abductor pollicis brevis muscle. Four FMTT traces were completed 24 hours later, to assess retention. RESULTS: Following motor acquisition, SEP peaks associated with somatosensory processing at the level of the spinal cord (N11 and N13) increased in the control group, with minimal change in SCNP; while somatosensory cortex peaks (N20 and P25) increased in the control group and decreased for the SCNP group. The N18 increased for both groups, but to a greater extent in the control group. The N30 SEP peak increased in the control group with no change in the SCNP group. Both groups showed small increases in the N60 SEP peak. Both groups showed improved absolute and relative motor performance accuracy across the three timepoints. SCNP participants had greater absolute performance error at baseline vs controls, which reduced post-acquisition and was then similar to the healthy control group at retention. Relative to baseline, there were greater proportional increases in performance accuracy in the SCNP group vs the control group at retention. CONCLUSIONS: Preliminary results indicate differential changes in SEP peaks associated with sensorimotor integration and somatosensory processing following motor acquisition of the FMTT in SCNP. The SCNP group was worse at baseline, however both groups improved at post-acquisition and retention. This suggests a greater initial reliance on feedback, possibly due to altered feedforward control in the SCNP group. A larger sample size is needed to confirm these findings.

O12.2 Brain neuroimmune and sensorimotor function in mechanism-based subgroups of individuals with low back pain

Muath Shraim[1], Hugo Massé-Alari[2], Michael Farrell[3], Marco Loggia[4], Paul Hodges[1]
[1]The University of Queensland, [2]Université Laval, [3]Monash University, [4]Harvard Medical School

BACKGROUND AND AIM: Recent work has highlighted the involvement of neuroinflammation (i.e., glial cell activation) in the sensorimotor cortex (S1/M1), in addition to other areas of the brain and spinal cord, in individuals with chronic low back pain (LBP). Because of the diverse role of glial cells in regulation of neural function (e.g., neurotransmitter availability, glucose storage, immune functions, synaptic pruning, etc.) it is plausible that neuroinflammation in S1/M1 might contribute to some of the sensorimotor changes that are commonly identified in individuals with LBP. Further, as these sensorimotor features and neuroinflammatory mechanisms are thought to differ between pain with different underlying neurobiological mechanisms (e.g., pain maintained by nociplastic vs. nociceptive mechanisms) it is possible that such a relationship might be mechanism-specific. This study aimed to: (1) compare glial activation in S1/M1 between healthy individuals and two groups of individuals with chronic LBP, one group with features consistent with an ongoing nociceptive contribution to pain and the other with likely nociplastic mechanisms; and (2) evaluate relationships between glial activation and measures of sensory and motor function. METHODS: Simultaneous PET-fMRI was used to measure glial activation in functionally defined regions of S1/M1 in painfree individuals and individuals with chronic LBP who were sub-grouped according to clinical criteria into primary nociceptive and nociplastic pain mechanism groups. The somatotopic regions of M1 and S1 related to the low back were identified using fMRI during standardized motor tasks and thermal stimuli. In a separate session, sensorimotor measures included single and paired-pulse transcranial magnetic stimulation (TMS) and quantitative sensory testing (QST). Sleep, depression, disability, and pain questionnaires were administered. RESULTS: Glial activation was significantly greater in the lower back cortical representation of S1/M1 for individuals with LBP group who presented with clinical features consistent with primary nociplastic pain than both nociceptive LBP and painfree groups. The nociplastic LBP group had lower corticospinal excitability (measured with TMS recruitment curve). Glial activation in S1/M1 was weakly negatively correlated with intra-cortical facilitation (r=-0.41), positively correlated with greater remote hot (r=0.52) and cold (r=0.55) pain sensitivity, and positively correlated with poor sleep, depression, functional disability and BMI. CONCLUSIONS: This study provides evidence for neuroinflammation in S1/M1 of the brain that is greater in individuals with clinical features that suggest predominant nociplastic pain mechanisms. Glial activation was associated with sensorimotor and clinical features. Although this cannot be interpreted as causal, the data provide foundation to speculate on possible mechanisms to be interrogated in future studies.

O12.3 Motor adaptation to movement-evoked pain induced during lumbar flexion

Valter Devecchi[1], Deborah Falla[1], Helio Cabral[1], Jacques Abboud[2], Paul Hodges[3], Alessio Gallina[1]
[1]University of Birmingham, [2]Université du Québec à Trois-Rivières, [3]The University of Queensland

BACKGROUND AND AIM: Low back pain is often exacerbated or relieved by specific movements [1]. Tonic pain models have been used to investigate motor adaptations [2] to pain while reducing the impact of confounders associated with clinical pain conditions. However, tonic pain fails to reproduce some of the temporal characteristics of clinical pain, including the association between pain and movement. Here, we used a movement-evoked experimental pain model [3] to investigate how people adapt their motor strategies when lumbar flexion is a pain-provocative movement. METHODS: Sixteen healthy adults lifted a 1kg box between two shelves placed at knee and eye level for 15 sets of 10 cycles each. Experimental pain was induced in the lumbosacral region (sets 3-13) with electrical stimulation using a sinusoidal waveform at 4 Hz and participants were asked to rate the amount of perceived pain intensity. The stimulation was modulated in real time proportionally to the amount of lumbar flexion

and set to induce a pain intensity of 5/10 when lumbar flexion was equal or higher than the peak of flexion recorded at baseline (sets 1 and 2). Lumbar kinematics and activation of the right erector spinae were collected using inertial measurement units and high-density surface electromyography (16x4 electrodes, caudal row aligned with L4/L5). The intensity of muscle activation and cranio-caudal location of the centroid of activity were measured in a 500 ms window centred on the lumbar flexion peak. Changes in lumbar kinematics (peak flexion and extension), intensity of muscle activation and location of the centroid between baseline (sets 1-2), early adaptation (sets 3-4), late adaptation (sets 12-13), and post-pain (sets 14-15) were assessed using repeated-measures ANOVA. RESULTS: Pain ratings did not change significantly (p=0.12) from early (3.1/10) to late adaptation (2.5/10). Compared to baseline, participants reduced lumbar flexion by 9.3±19.5% in the early adaptation (p=0.26), 17.7±26.0% in the late adaptation (p<0.05) and 16±23.8% post-pain (p<0.05). Activation of the erector spinae increased during the painful stimulation by at least 15% in 8 participants and decreased by at least 15% in 4 participants. People who reduced lumbar flexion more showed a larger increase of muscle activation (r=0.55, p<0.05) and a cranial shift of the centroid (r=0.51, p=0.06, Figure), especially during the early adaptation phase. CONCLUSIONS: As people reduced lumbar flexion during movement-evoked lumbar pain, our findings support the role of purposeful motor adaptation as a potential strategy to avoid pain-provocative movements [2]. Adaptation was more evident across trials and outlasted pain, which may suggest that the absence of pain is not sufficient to immediately restore the original motor strategy. Finally, heterogeneous changes in muscle activity suggest that individual-specific neuromuscular strategies are used to adapt to pain. REFERENCES: [1] Rabey M, et al. 2017; Scan J Pain 16:22-28. [2] Hodges PW, et al. 2011; Pain 152(3): S90-S98. [3] Gallina A, et al. 2021; J Physiol 599: 2401-2417.

O12.4 Task-relevant pain reduces knee extension torque more than tonic pain.

Hélio Cabral[1], Valter Devecchi[1], Chelsea Oxendale[1], Ned Jenkinson[1], Deborah Falla[1], Alessio Gallina[1]
[1]University of Birmingham

BACKGROUND AND AIM: Pain reduces the maximal voluntary contraction (MVC) of the knee extensors [1]. Commonly, injections of hypertonic saline are used to induce experimental knee pain, resulting in pain that does not change with movement [1]. In contrast, people with painful knee disorders often experience pain that is exacerbated by specific movements. As motor adaptation to pain is thought to be purposeful strategy to limit pain [2], this study investigated whether pain that increases with muscle contraction has a larger effect on knee extension torque than a constant painful stimulation. METHODS: Twenty-one healthy volunteers performed three isometric knee extension MVCs without pain (baseline) and during experimental knee pain (tonic or task-relevant, randomised). Pain was induced on the infrapatellar fat pad using sinusoidal electrical stimuli at 10 Hz to induce a maximum pain intensity of 4/10 (numeric rating scale). In the tonic pain condition, the stimulation was continuous. In the movement-evoked pain condition, the stimulation was modulated proportionally [3] to the amount of knee extension torque, so that the current to induce a pain intensity of 4/10 was delivered when the knee extension torque was >90% of peak torque measured at baseline. Peak torque and peak vastus lateralis (VL) and biceps femoris (BF) activation (root mean square amplitude, RMS) were averaged across the three MVCs and values collected during the painful condition were normalised with respect to baseline. T-tests (or non-parametric equivalent) were used to identify whether torque or RMS differed during pain compared to baseline, and between tonic and task-relevant pain. RESULTS: During tonic pain, participants reported greater pain intensity at rest (3.7/10) compared to during contraction (2.3/10, p<0.001), while the opposite was observed during task-relevant pain (1.3/10 at rest, 3.0/10 during contraction, $p<0.001$). Knee extension torque decreased during both tonic (9.8%, $p<0.001$) and task-relevant pain (16.3%, $p<0.001$) and larger reductions were observed during task-relevant compared to tonic pain ($p=0.004$, panel A). VL activation also decreased during both tonic (7.5%, $p=0.048$) and task-relevant pain (17.6%, $p<0.001$), but no significant differences were observed between conditions ($p=0.116$; panel B). In contrast, BF activation decreased for task-relevant (19.9%, $p=0.002$), but not for tonic pain (7.4%, $p=0.186$), with a larger reduction observed during task-relevant pain ($p=0.026$; panel C). CONCLUSIONS: Similar to previous research [1], tonic knee pain resulted in less pain during contraction and a consistent decrease in torque. Our results indicate larger motor adaptation to pain when pain is movement-evoked, suggesting that pain modulated by the task is a stronger stimulus for adaptation than tonic pain. REFERENCES: [1] Salomoni et al. 2016; Plos One 11(8): e0161487. [2] Hodges et al. 2011; Pain 152: S90-S98 [3] Gallina et al. 2021; J Physiol 599: 2401-2417.

Saturday June 25, 2022

Oral 13 – Modelling and Signal Processing

O13.1 Towards fast and accurate portable technology for subject-specific neuromusculoskeletal assessment

Donatella Simonetti[1], Bart F. J. M. Koopman[1], Massimo Sartori[1]
[1]*University of Twente*

BACKGROUND AND AIM: Rapid and quantifiable estimates of an individual's neuromusculoskeletal (NMS) functionality are key for the reliable assessment of movement capacity in healthy or pathological populations. While rapidity can be achieved using subjective and simplistic methodologies such as the functional ambulatory categories (FAC) in clinics, quantifiability requires advanced, costly and lengthy technologies, such as motion tracking systems and electromyography (EMG). However, the time-consuming, non-systematic localization of individual muscles and manual EMG sensors' placement hamper the use of advanced technologies for rapid and repeatable quantitative measurements. We aim to merge rapidity and NMS quantifiability by integrating (1) a soft sensorized garment comprising 64 equally distributed monopolar EMG electrodes and next also inertial measurements units (IMUs), (2) a clustering algorithm for fast and automatic localization of the muscles lying under the multi-channel (MC) EMG grid, and (3) a computationally efficient NMS model. We present preliminary results toward the realization of such technology. METHODS: A healthy subject was instrumented with a lower leg sock sensorized with 64 equally distributed monopolar electrodes, 33 reflective markers and 8 IMUs (torso, pelvis and each shank, thigh and foot). The subject was instructed to walk at three speeds (1, 3 and 5 km/h) on an instrumented split-belt treadmill. The 64-EMGs signals were processed with chained non-negative matrix factorization (NNMF) to extract 5 activations specific for the 5 main lower leg muscles, Tibialis Anterior, Peroneus, Gastrocnemius Medialis and Lateralis, and Soleus. Afterward, both marker trajectories and quaternions from IMUs were processed to compute joint angles as well as reference ankle moments and muscle-tendon unit (MTU) kinematics. Both MTU kinematics retrieved from markers or IMUs and automatically retrieved muscle-specific activations were input to an EMG-driven NMS model to estimate ankle torque. RESULTS: We demonstrated the potential of NNMF to extract muscle-specific clusters from unknown located electrodes using a single locomotion speed (R^2= 0.72 ± 0.8 against manually selected channels) as well as applying the same clusters on unseen walking tasks. Secondly, we determined how accurate the quaternions from IMUs were and what role their accuracy played in precise EMG-driven NMS simulations. We found that quaternions can be employed to retrieve joint moments with an accuracy close to that of marker trajectories (R^2 = 0.86 ± 0.05). CONCLUSIONS:

The combination of fully wearable technologies with automatic MC-EMG clustering and NMS modeling technique can allow understanding individual muscle function and hence drastically change the way the musculoskeletal assessment is performed. Rapid and quantitative estimates on internal subject-specific NMS properties can be crucial in clinical-decision making, rehabilitation, sports training and injury prevention.

O13.2 The effect of sEMG amplitude estimation techniques on force tracking

Simone Ranaldi[1], Giovanni Corvini[1], Cristiano De Marchis[1], Silvia Conforto[1]
[1]University Roma TRE

BACKGROUND AND AIM: Surface electromyography has been hypothesized to yield relevant information about the force that is generated by muscles. The most widespread theories for the sEMG-force relationship modeled the force as a linear function of the sEMG amplitude. However, this holds only for submaximal isometric contractions. These models can describe static or quasi-static contractions; for the dynamic case the relationship between force and amplitude is not clear and its determination is prevented by many factors, both technical and physiological. In any case in dynamic conditions the amplitude of the sEMG signal varies in time also rapidly and for the estimation of the envelope adaptive algorithms become therefore necessary. METHODS: To investigate how different sEMG amplitude estimation techniques affect force estimation, a simple isometric force tracking experiment was designed, in which subjects were asked to follow a reference force signal oscillating between three different force levels, namely 10, 20 and 40% of the maximal value, in a cyclical fashion with 10s intervals by using their dominant triceps brachii. Force and sEMG signals were recorded and the envelope of the sEMG signal was extracted via moving window RMS with different fixed window lengths and an automatic adaptive procedure (Ranaldi S et al. JEK, 42, 1-9.). All the envelopes were then tested in terms of their correlation with the force signal during the dynamic phases of the contractions (i.e. the changes in force level). For the experiment, data from 16 healthy subjects were recorded. RESULTS: Results showed that longer time-constant (200-500ms) filters perform better in correlating with the force signal. The adaptive filter reached correlation levels that are comparable with the ones coming from the best performing fixed window filters, although the average window length was significantly shorter. The adaptive method identified the optimal window to be around 70-75ms when approaching the onset and offset phases, while for the constant phases this value rises to approximately 90ms. The fixed window filters with time constants that are matched with the values coming from the adaptive procedure resulted in sEMG-forces correlation values that are 5-10 % lower in all conditions. CONCLUSIONS: The results of this study showed in a quantitative way how different envelope extraction techniques might affect the analysis of the sEMG-force relationship even when the contractions are slow and quasi-static with respect to the analyzed time constants. Moreover, the comparison between the adaptive algorithm and classical filters with comparable dynamics emphasized that the time constant is not the only factor to influence the estimation. The window length coming from the adaptive algorithm were very repeatable across different repetitions of the same contraction, suggesting that the time varying filter was capturing additional information on the force output that would have been impossible to reveal using standard low-pass filters.

O13.3 Automatic jitter measurement in electromyographic signals

Armando Malanda[1], Daniel Stashuk[2], Oscar Garnés[3], César Valle[1], Javier Rodríguez-Falces[1], Javier Navallas[1]
[1]Public University of Navarra, [2]University of Waterloo, [3]University Hospital of the Fundación Jiménez Díaz

BACKGROUND AND AIM: Variability in the generation times of the fibre potentials of motor units ("jitter") is increased in pathological or degenerative processes that affect the neuromuscular junction or motor neuron. Traditionally, "jitter" has been measured using single fiber electrodes and a manual technique that is difficult and subjective. Moreover, these electrodes are expensive and reusable and thus imply a potential risk of patient infection. Gradually they are being substituted by concentric needle electrodes, which are reusable. As these electrodes are larger, they capture the electrical potentials from a larger number of fibers; which are therefore more overlapped in time, making jitter measurement more difficult. This work presents an automatic method to estimate the "jitter" from motor unit potential (MUP) trains, which is valid for signals recorded using concentric needle electrodes. METHODS: In short, intervals, within the duration of a MUP, with a high probability of being formed by only one muscle fiber potential (MFP) are detected. Then "jitter" measurement is performed between pairs of these intervals using an algorithm which incorporates the traditional mean consecutive differences (MCD) technique. This technique prevents artifactual raising or lowering of the jitter measurement due to needle movements during the recording operation. To evaluate the method, electromyographic (EMG) signals were recorded from patients suffering disorders of the neuromuscular junction or neuropathic diseases of several types using a Keypoint system at the Fundación Jiménez Díaz University Hospital, Madrid (Spain). These signals were then decomposed by the DQEMG software into several MUP trains. A Matlab-based graphical tool was also implemented for manual jitter measurement, including functionalities for discarding potentials and selecting peaks or slopes for triggering. Jitter was measured across a bank of 82 MUP trains using the automatic and manual methods. RESULTS: Comparative analysis yielded a mean of jitter differences (bias) of 1.74 µs, a mean of absolute differences of 2.73 µs and values of -2.62, -0.35, 2.53 and 7.56 µs for the 5th, 25th, 75th and 95th percentiles of the statistical distribution of the differences, respectively. CONCLUSIONS: Although more extensive tests are still to be done, these results suggest that the proposed automated jitter measurement method may be a valuable technique for clinical practice.

O13.4 A mixed integer linear programming model for the optimal resolution of complex superpositions of motor unit action potentials

Francesco Negro[1], Renata Mansini[1], Roberto Zanotti[1]
[1]Universita' degli Studi di Brescia

BACKGROUND AND AIM: Spike sorting techniques are essential tools to resolve compound neural activity into individual neuron contributions. When two or more neurons discharge with small or no delay, the recorded action potential results from the superposition of the action potentials of the individual neurons. For example, during voluntary contractions, the concurrent activity of tens of motor units can be recorded by intramuscular and surface electromyographic recordings. In these signals, the probability and the complexity of the superpositions increase with the number of active motor units and their average discharge rates. Unfortunately, the resolution of the overlapped activity of several motor unit action potentials is a complex task that requires the solution of a combinatorial problem involving all possible available motor unit action potentials and relative delays. The exhaustive search of solutions to such problems is usually impractical due to its computational complexity. METHODS: To overcome this limitation, we formulate the resolution problem as a mixed-integer linear programming model solved to optimality using a general mathematical optimization solver. We simulated 1000 overlapping potentials extracted from a previously used dataset, and we compared the performance of our proposed approach with a state-of-the-art algorithm, the branch and bound (BB) [1], in terms of both

accuracy and computational requirements. The superpositions were simulated using 2 to 10 motor unit action potential templates with relative delays of ±1 ms. RESULTS: Results showed similar accuracies (%) between our approach and the BB for superpositions involving 2 (100.00(0) vs 99.60(4.99)), 3 (100.00(0) vs 99.02(5.96)) and 4 (100.00(0) vs 96.68(10.75)) motor unit action potentials. However, using a larger number of MUAP templates (5-10), our method outperformed the BB algorithm in terms of accuracy for 5 (100.00(0) vs 94.23(13.28)) and 6 (99.98(0.53) vs 89.58(17.52)) templates. Additionally, the computational time of our approach increased almost linearly with the number of templates in comparison to an exponential growth of the BB. Specifically, the BB was impractical for resolving superpositions involving 7 or more MUAP templates. In these cases, our approach showed high accuracies for 7 (100.0(0)), 8 (99.90(1.25)), 9 (99.91(1.11)),and 10 (99.92(1.09)) templates with a computational time of less than a 1s. Interestingly, our approach could be easily extended to the multichannel case with a significant improvement in accuracy performance. CONCLUSIONS: In conclusion, we proposed an innovative solution for the resolution of overlapping action potentials, highly flexible, that can be easily generalized to different types of action potential recordings, and able to resolve superpositions involving a large number of action potentials. [1] Mc. Gill, 2002

O13.5 Identifying Optimum Time Delay Embedding Parameters for Nonlinear Surface EMG Analysis

Matthew Flood[1], Lara McManus[2], Sageanne Senneff[3], Diego Pereira Botehlo[3], Madeleine Lowery[3]
[1]Luxembourg Institute of Health, [2]Trinity College Dublin, [3]University College Dublin

Intro: There has been a recent growth in the number of studies applying nonlinear dynamics measures, such as entropy, Lyapunov exponents and recurrence quantification analysis (RQA) to estimate the complexity of the underlying neuromuscular system from the surface EMG (sEMG) signal. Estimation of these nonlinear measures from time series data requires phase space reconstruction, conventionally using time delay embedding based on Takens' theorem. However, studies to-date have not tailored these parameters for sEMG analysis, instead choosing parameters based on those commonly used for physical models. In this study we use simulations from an anatomically-based EMG model to determine the optimal time delay (τ) and embedding dimension (m) parameters for nonlinear analysis of sEMG during isometric contraction. Methods: SEMG signals from 4 adjacent bipolar electrode pairs were simulated by convolving MU firing times, obtained using the motoneuron model described in [1] (Fig. 1), with MU action potentials (MUAP) generated from an anatomically accurate model of the first dorsal interosseous muscle [2]. The dataset consisted of sEMG from 20 different MUAP subsets, simulated at 4 muscle contraction force levels (10-40% MVC) and with 3 conduction velocities (CV = 75%, 100%, 125%). For each modelled sEMG, time delay parameters were estimated at 5 sampling frequencies and 4 SNR levels. Optimum values for <i>m</i> were identified using the averaged false nearest neighbours method proposed by Cao [3], up to a maximum dimension of 50. Optimum values for τ were identified using the first minimum of the mutual information function proposed by Fraser and Swinney [4] up to a maximum delay corresponding to 100ms (10Hz) for that signal. Results: Optimal values of τ = 1, 2, 4 and 10 were identified for sEMG sampled at 500, 1000, 2000 and 5000Hz, respectively (i.e. increased linearly by 1 every 500Hz). This linear relationship remained consistent up to 10kHz in the presence of added noise. Optimal values for <i>m</i> ranged from 5-8 for sEMG sampled at 1kHz, remaining consistent across force levels. Conclusions: To reliably quantify nonlinear neuromuscular behaviour from sEMG, parameters for phase space reconstruction must be selected accurately as incorrect parameter selection is likely to misrepresent the true dynamics of the underlying neuromuscular system. This study demonstrates that commonly used embedding parameters in sEMG analysis (m=2, τ=1) may lead to inaccurate values of nonlinear measures. Refs: [1] Senneff, et al., (2019). 41st IEEE EMBC (pp. 2293-2296). [2] Pereira Botelho, et al., (2019). PLoS computational biology, 15(8), e1007267. [3] Cao (1997) Physica D: Nonlinear Phenomena 110.1-2: 43-50. [4] Fraser & Swinney, (1986) Physical review A 33.2: 1134.

O13.6 A spatio-temporal ICA framework to identify lumbar muscle activity from high density surface EMG

Amin Nasrabadi[1], Jacques Abboud[2], Alessio Gallina[1], Calvin Kuo[1], Jean-Sébastien Blouin[1]
[1]University of British Columbia, [2]Université du Québec à Trois-Rivières

BACKGROUND AND AIM: The deep and superficial lumbar muscles act synergistically on the spine to maintain posture and generate axial movement. Although weakness and atrophy of the deep lumbar muscles (e.g. multifidus) have been associated with chronic low back pain, our understanding of lumbar muscle function has been limited by the necessary use of invasive indwelling muscle recordings (particularly for the deep muscles). Consequently, there is a critical need for methods to characterize deep and superficial lumbar muscle activation with non-invasive methods, e.g. surface electromyography. Here, we present a novel framework to identify the activation of individual lumbar muscles and region within a muscle from signals recorded with high-density surface electromyography (HDsEMG). METHODS: The framework decomposes the HDsEMG signals into independent sources using Spatio-temporal independent component analysis (stICA) to match lumbar muscle recordings obtained with indwelling electrodes. Spatio-temporal ICA permits a trade-off between spatial and temporal independence, an approach well adapted to the multiple motor units recorded with HDsEMG during distinct tasks. To validate the framework, we recorded simultaneous EMG activity from four lumbar muscles (deep multifidus; superficial multifidus; caudal longissimus and cranial longissimus) using indwelling electrodes and a 64 surface electrode matrix (5 X 13, one missing electrode; HDsEMG) positioned over the skin laterally to the L1-L5 vertebrae. Eleven participants (4 females, 7 males, age 27.6±3.2, weight 67.2±9.4 kg, height 1.74±0.08 m) were asked to perform 10 tasks, each repeated twice. First, we visually inspected the indwelling and HDsEMG recordings to include clean data with activation on most channels. We then rectified, low-pass filtered (cutoff frequency of 100Hz) and normalized the monopolar HDs/EMG signals to have a zero mean and standard deviation of one. Next, we performed a Principal Component Analysis (PCA) on the HDsEMG signals to seed the temporal and spatial components before applying the stICA. Finally, the top four components sorted by eigenvalues of the PCA were fed into the stICA. Correlation coefficients were computed to determine the association between signals decomposed from stICA and indwelling muscle recordings. RESULTS: The correlation coefficients between indwelling electrodes and stICA components ranged between 0.15 to 0.42. Also, the location of the components from the stICA was visually spatially distinct on the surface HDsEMG recordings. The present results suggest that HDsEMG signals can extract components weakly representative of individual lumbar muscle activation CONCLUSIONS: Future work is needed before such methods can be applied to characterize muscle activation from the deep and superficial lumbar muscles. We intend to seed the stICA algorithm with spatial components through a constrained ICA that allows the use of prior information about the signals. Further developments will ultimately lead to a better understanding of the role of the multilayered lumbar spine and their (dys)function in persons from clinical conditions such as chronic low back pain.

O13.7 Time Series Heatmaps as a Visualization Approach to Clustering Biological Time Series Data

Kassy Raymond[1], Andrew Hamilton-Wright[1], Kristel Thomassin[1]
[1]University of Guelph

BACKGROUND AND AIM: Clustering is an unsupervised machine learning technique that is used to group similar points in a dataset from the dissimilar. In biosignal processing, clustering can be used to identify noise, artifacts, and anomalies in the signal and separate periods of physiological response from baseline events. However, clustering using signal data is often difficult to interpret in the context of the underlying physiological information source due to feature calculation that requires transitioning from the time to the feature space. Using Electrodermal Activity (EDA) data as an example, we present time-series heatmaps, a novel method to visualize cluster assignments across a time series. We discuss the insights that can be drawn between and across the signals of participants using our visualization approach. METHODS: 90 second windows were calculated on EDA signals obtained simultaneously from Biopac and the Empatica E4 acquisition devices. 10 features were calculated on each window, for each participant providing physiologically relevant signal summary information, such as peak frequency, amplitude, etc. Density-Based Spatial Clustering of Applications with Noise (DBSCAN) was used to cluster input feature data after projecting it through a PCA (Principal Component Analysis) dimensionality reduction step. This provides us projected data in an information rich space suitable for applying clustering while allowing us to retain a direct link through temporal index to both the original and windowed data. Using this index, we can then use visualization tools to explore and validate the results of the clustering algorithm. Heatmaps were employed as an information rich method to provide analysts access to the full data display while simultaneously identifying regions and even individual events of interest. RESULTS: Figure 1 visualizes the heatmap display of the output of the analytical pipeline described above applied to a single data set. The rows in the heatmaps represent signals from participants where each window from each participant contributes the set of patches making up a row. The resulting clustering is shown in time-series form by using the window index to colour a specific time period for each participant, producing a visual representation allowing insight based on the clustering tool analysis. Figure 1 (a) shows the heatmap generated at window length 3; part (b) displays a longer window length. Outliers, problematic recordings, and underlying structure are all apparent in these images. This allows visual inspection of the division of time samples by cluster number and provides a means for clearer and deeper understanding of the relationship between participants within a single treatment, and across treatments. Time indexing provides an immediate link to the underlying raw and decomposed signal source (not shown in figure). CONCLUSIONS: The application of clustering combined with the visualization of the results using time-series heatmaps allowed us to efficiently and clearly explore electrophysiological data and link observed phenomena with the underlying signal source.

Oral 14 – Motor Control and Motor Learning

O14.1 People with Diabetic Peripheral Neuropathy Exhibit Deficits in Predictive Precision Grip Force

Marcio dos Santos[1], Abdalghani Yahya[2], Patricia Kluding[2]
[1]University of St Augustine for Health Sciences, [2]University of Kansas Medical Center

Purpose: This study aims to investigate the impact of type 2 diabetes (T2D) and diabetic peripheral neuropathy (DPN) on grip force control (GFC). DPN is a major complication of T2D affecting sensory and motor nerves. Therefore, T2D and DPN might impact the ability to perform hand tasks such as picking up

objects, household chores, and monitoring blood sugar. To perform these tasks efficiently, a precise GFC is required, in which grip force is adjusted in parallel to load force changes generated from lifting and holding an object in space. The central nervous system (CNS) regulates predictive and reactive GFC via feedforward and feedback mechanisms, respectively. Subjects: The study included 3 age-matched groups: 12 healthy participants (7 males, 58±6 years), 11 participants with T2D without DPN (T2D-alone) (5 males, 61±6 years), and 13 participants with T2D and DPN (T2D+DPN) (6 males, 60±6 years). Materials and Methods: We derived GFC variables from a task that involved a series of lifting-and-holding a cup-shaped instrumented object. The grip force ratio (GFR, grip force/load force), calculated during the lifting phase, and the static force (SF; N) resulting from the holding period, represented the predictive and reactive grip force, respectively. We also calculated the latency (ms), the coordination between grasping and lifting the object initially, and the time-lag (ms), the coordination between grip and load force during lifting, both are predictive. We compared all the variables between groups using a one-way ANOVA and Kruskal-Wallis test. We used post-hoc analysis for subsequent comparisons. Results: GFR and latency showed significant differences between groups (p=0.013 and p=0.025, respectively). GFR: T2D+DPN group (mean±SD; 3.67±0.84) showed larger ratios as compared to T2D-alone (2.87±0.66; p=0.018) and healthy controls (2.76±0.84; p=0.007). Latency: T2D+DPN group (465.64±180.73) showed longer time as compared to T2D-alone (373.48±168.84; p=0.054) and healthy controls (307.92±42.44; p=0.009). No significant differences were found between T2D-alone and healthy controls for GFR (p=0.75) and latency (p=0.55). There were no significant differences between the groups for SF (p=0.22) and time-lag (p=0.79). Conclusion: People with T2D+DPN exhibit deficits in predictive force and coordination to initiate the lifting movement (latency). Unprecise predictive force and latency may represent the inability to obtain, integrate, and store information from objects (weight, size, and shape) properly, which in turn disrupts the execution and coordination of precise forces during subsequent object's liftings. In contrast, people with T2D-alone have their GFC preserved. Clinical Relevance: Clinicians should be aware that DPN affects not only the peripheral nervous systems but also the CNS. These deficits might expose people with T2D and DPN at risk of fatigue, low dexterity, and hand/arm injuries. The GFC study improves neurological screening and may enrich physical therapy interventions. Future studies should investigate strategies to help better adjust grip forces during object manipulation.

O14.2 Reduced lumbar extensor muscle torque steadiness is associated with increased activity of the lumbar erector spinae muscle during eccentric contractions in people with chronic low back pain

Michail Arvanitidis[1], David Jiménez-Grande[1], Nadège Haouidji-Javaux[1], Deborah Falla[1], Eduardo Martinez-Valdes[1]

[1]Centre of Precision Rehabilitation for Spinal Pain (CPR Spine), School of Sport, Exercise and Rehabi

BACKGROUND AND AIM: People with chronic low back pain (CLBP) commonly demonstrate impaired lumbar extensor isometric muscle force accuracy compared to asymptomatic (AS) controls. An additional measure of force (torque) control is torque steadiness (TS), i.e., the ability of an individual to exert steady torque during a submaximal voluntary contraction. The generation of smooth torque is crucial for physical function, and reductions in TS can influence the precision of movements. To date, it is unclear whether TS is also altered in people with CLBP and if so, the neuromuscular mechanisms responsible for the poorer lumbar extensor torque control also remains unclear. We investigated if individuals with CLBP display reduced TS compared to AS controls during eccentric contractions of the lumbar extensors and the neuromuscular mechanisms underlying the control of TS by utilising high-density surface electromyography (HDEMG). METHODS: 12 individuals with CLBP and 12 AS controls were included. Submaximal eccentric lumbar extensor TS was measured with an isokinetic dynamometer during torque target-tracking contractions at 25% and 50% of their maximal voluntary contraction (MVC). HDEMG signals were acquired from their lumbar erector spinae (ES), rectus abdominis and external oblique muscles in monopolar mode, using four grids of 64 equally spaced (8mm) electrodes. Two grids were placed over the lumbar ES on the same side to form a larger grid. The monopolar signals were differentiated longitudinally in the presumed direction of the muscle fibres for each muscle to form adjacent bipolar channels. Root mean square (RMS) was determined as an average for all electrode pairs. TS was characterised by the standard deviation (SD) and the coefficient of variation (CV) of the torque signal. Pearson correlation coefficient (r) was used to assess the degree of linear association between variables. RESULTS: Overall, the magnitude of ES muscle activation during the TS contractions was higher in people with CLBP ($p<0.001$), accompanied by lower TS ($p<0.001$). A strong association between ES EMG amplitude and TS was observed in people with CLBP ($r=0.587$, $p=0.045$), but not in the AS controls ($r= 0.367$; $p=0.241$). The centre of ES muscle activity in the region of the grid and the co-activation levels did not differ between groups, likely suggesting that the reductions in TS observed in people with CLBP cannot be explained by these HDEMG features. CONCLUSIONS: This study provides new insights into the behaviour of the lumbar ES muscle during eccentric contractions in people with CLBP. The lower TS observed in people with CLBP was associated with increased ES EMG amplitude (higher energetic cost).

O14.3 High-density surface electromyography is reliable in assessing characteristics of trunk extensors during static and dynamic tasks

Joeri van Helden[1], Shin-Yi Chiou[1], Eduardo Martinez-Valdes[1], Paul Strutton[2], Deborah Falla[1]
[1]University of Birmingham, [2]Imperial College London

BACKGROUND AND AIM: High-density surface electromyography (HDsEMG), which involves recording muscle activity from multiple arrays of electrodes, can be used to assess the spatial distribution of muscle activity. While reliability of HDsEMG has been reported for muscles of the limbs, it has not been established for axial muscles, such as the Erector Spinae (ES), a trunk extensor. The study aimed to establish intra- and inter-session reliability of HDsEMG-derived parameters from the ES during static and dynamic goal-directed voluntary movements, and during functional reaching tasks where the ES acts as a postural muscle. METHODS: Twenty healthy participants (age 27.9 ± 4.9 years; weight 68.25 ± 11.08 kg; height 169.5 ± 8.5 cm; 10 males; 18 right-handed) performed: 1) static trunk extension (Ito test) and reverse trunk extension, 2) dynamic trunk flexion and lateral trunk flexion, and 3) multidirectional functional reaching tasks. During the tasks, ES activity from the 8th to 12th thoracic vertebrae was recorded using two electrode grids (64 monopolar channels each). The same procedures were repeated in all participants on a different day (between-session interval: 7.5 ± 1.2 days). Root Mean Square (RMS), barycenter, Mean Frequency (MNF), and entropy were derived from differential HDsEMG, and Intra-class Correlation Coefficient (ICC; mixed model, absolute agreement) was calculated for these parameters. RESULTS: Good to excellent within-session reliability was found for RMS (ICC .91 - .98), barycenter (.88 - .99), MNF (.88 - .97), and entropy (.79 - .97) for all tasks. Between-session reliability varied across parameters and tasks. For static trunk extension and reverse trunk extension, moderate to excellent reliability was found for all parameters (.62 - .97), albeit poor reliability was found in entropy for the reverse trunk extension. For dynamic trunk flexion and lateral trunk flexion, moderate to excellent reliability was found in RMS (.85 - .92) and MNF (.66 - .93), whereas poor to good reliability

was found in entropy (.23 - .51) and the barycenter (.23 - .77). For multidirectional reach tasks, good to excellent reliability was found in RMS (.82 - .91) and MNF (.81 - .92), while poor to excellent reliability was found in barycenter (.49 - .92) and entropy (.21 - .84). CONCLUSIONS: RMS and MNF derived from the HDsEMG show consistent within- and between-session reliability in goal-directed voluntary movements and postural tasks of the trunk. Hence, HDsEMG is a reliable tool for assessing characteristics of the ES muscle and therefore suitable to be used in quantifying changes in neuromuscular function.

O14.4 Strategies of improving a concurrent force-trajectory matching skill with two fingers

Mitchell St. Pierre[1], Minoru Shinohara[1]
[1]*Georgia Institute of Technology*

BACKGROUND AND AIM: Real-world tasks are often a complex combination of motor outputs that are grouped within a hierarchy. It is unknown what strategies a healthy young adult population might employ to improve performance during a complex visuomotor task that requires concurrent force adjustments of two fingers. The purpose of the study was to understand the strategy of improving concurrent control of the index and little fingers to match complex force trajectories with training. METHODS: Twenty-four healthy young adults (21.4 ± 3.5 years, eleven women) produced abduction forces with their index and little fingers to push against force transducers to match the individual forces with a complex target force pattern as accurately as possible. The target pattern was composed of three low-frequency sinusoids centered around 5% of maximal voluntary contraction (MVC) force, with each sinusoid at a unique frequency (< 1 Hz), amplitude (< 3% MVC), and phase. The resulting pattern (< 10% MVC) spanned 20 s as the target. Subjects received instantaneous visual feedback for finger forces as two separate colored traces alongside the target pattern. Subjects were provided with a score based on the root-mean-square error (RMSE) from the target pattern after each trial. Force RMSE (mean of two RMSEs) and peak values of the cross-correlation function (CCF) between the index and little finger forces were analyzed across five sessions. Power spectra were computed for both finger forces and analyzed at each constituent frequency to examine the force amplitude at the target frequencies. Coherence between the finger forces was analyzed to examine the similarity of forces in the frequency domain. RESULTS: Force RMSE decreased (p < 0.01) while CCF peak value increased across practice sessions (p < 0.01). RMSE and the CCF peak value were negatively correlated (r = -0.820, R² = 0.672, p < 0.01), suggesting that the degree of temporal similarity between finger forces is positively related to the level of visuomotor skill. Coherence between the finger forces increased across practice sessions (p < 0.01), confirming the improvement of similarity between oscillatory forces. Deviations in power between finger force and target trajectory decreased significantly across sessions for the index finger (p < 0.01) but not the little finger (p > 0.05). Results imply that the adjustment of time lag may be involved in improving the little finger performance. CONCLUSIONS: Improvement of CCF peak value and coherence that accompanied reductions in RMSE suggests that healthy young adults may reduce task complexity by consolidating two individual finger motions into a single functional action to improve the complex two-finger performance. The performance components adjusted during the consolidation process can vary depending on the finger. Supported by National Institutes of Health (1R03NS106088-01A1)

O14.5 Motor units behavior and neural excitability of the gastrocnemii muscle in different horizontal foot positions

Thomas Cattagni[1], Simon Avrillon[2], François Hug[3], Marion Crouzier[4]

[1]*Nantes Université,* [2]*Department of Physical Medicine and Rehabilitation, Feinberg School of Medicine, Northwestern Univer,* [3]*Université Côte d'Azur,* [4]*KU Leuven*

BACKGROUND AND AIM. The distribution of activation between gastrocnemius lateralis (GL) and gastrocnemius medialis (GM) during submaximal plantarflexion depends on the position of the foot in the horizontal plane, i.e. whether the foot is internally (toes-in) or externally (toes-out) rotated. Specifically, performing a submaximal plantarflexion with the toes-in increases GL activation and decreases GM activation compared with toes-out. The origin of such changes of activation distribution between gastrocnemii is not known. The aim of the current study was twofold. First, we assessed the change in motor units (MU) behavior between foot positions. Second, we determined whether differences in the neural control of gastrocnemii between foot positions are accompanied by changes in corticospinal and spinal-loop excitability. METHODS. Nineteen young adults males (age: 25 ± 6 years) participated in the study. The study was divided in 3 experimental sessions in which participants were tested in toes-in and toes-out positions while sitting (knee extended, ankle at 0° of plantarflexion). First, GL and GM MU were decomposed from high-density surface electromyographic recordings during isometric contractions i) sustained at 10 and 20% of the maximal voluntary torque (MVT) to assess MU mean discharge rate, and ii) ramped from 0% to 30% of the MVT to assess the time threshold at which MU are recruited. Second, GL and GM corticospinal excitabilities were assessed at rest using transcranial magnetic stimulation through motor evoked potentials (MEP). Third, GL and GM spinal-loop excitabilities were evaluated at rest with the study of the Hoffmann (H) reflex and M wave recruitment curves, and the calculation of the ratio between the maximal H reflex and the maximal M wave (Hmax/Mmax). GM/GL ratios of MU properties, MEP amplitude and Hmax/Mmax were compared between foot positions. RESULTS. From toes-in to toes-out, the increase of GM/GL ratio for the MU mean discharge rate was significant at 20% MVT ($p < 0.05$) but not at 10% of the MVT ($p = 0.10$). The GM/GL ratio for the time threshold at which MU are recruited decreased significantly from toes-in to toes-out ($p < 0.05$). The GM/GL MEP amplitude ratio was not different between foot positions ($p = 0.17$), neither was the GM/GL Hmax/Mmax ratio ($p = 0.81$). CONCLUSIONS. This study was the first to investigate whether changes in motor coordination within a muscle group are associated to modulation of the central nervous system excitability. We provided evidence that from toes-in to toes-out, the neural drive of GM increased while it decreased for GL. However, these modulations were not accompanied by changes in corticospinal and spinal-loop excitabilities. This suggests that other neural mechanisms, such as a change in motor execution from the primary motor cortex, could be responsible for the observed modulations in gastrocnemii neural drive between toes-in and toes-out.

O14.6 Haptic guidance facilitates motor learning when visual feedback is not present during training

Thomas Augenstein[1], Christian Remy[2], Mary Koje[1], Rajiv Ranganathan[3], Chandramouli Krishnan[1]
[1]*University of Michigan,* [2]*University of Stuttgart,* [3]*Michigan State University*

BACKGROUND AND AIM Rehabilitation robots, in recent years, have received a great deal of attention from the research community as a means of maximizing a patient's dosage of intensive, task-specific training. One area of particular interest is whether haptic guidance from these robots (i.e., forces that guide a patient along a desired trajectory) can facilitate motor skill learning. Previous studies have investigated this question, but these studies typically offered some form of real-time visual feedback (i.e., visual quantification of error) to the participant. The presence of this visual feedback may dominate learning, making it difficult to detect learning due to haptic guidance. The isolated effects of haptic feedback on learning is particularly relevant for tasks that typically may not have such visual information during learning (e.g., gait re-learning). Therefore, this study evaluated whether haptic guidance from a rehabilitation robot can facilitate motor learning in the upper extremity if the effects of visual feedback were removed. METHODS To test this hypothesis, we recruited 26 right-handed participants with no history of neurological or orthopedic conditions to practice a motor skill (tracing a circle) with their non-dominant hand. Throughout the experiment, the participants were only able to see a screen in front of them, i.e. they were blinded to their arms and the robot. The screen displayed the task in one of two conditions: with visual feedback or without visual feedback. Visual feedback consisted of the target trajectory (the circle), the desired position on the trajectory (a cursor traversing the trajectory at a constant speed), and the participant's position (a cursor coinciding with the participant's hand). When visual feedback was removed, the participant's position was made invisible. All participants performed 100 training trials during which they practiced tracing the circle without visual feedback. For roughly half of the participants (n = 12), a robot offered haptic guidance to assist them in staying on the path and for the remaining participants (n = 14) no haptic guidance was provided. To account for the effect of drift due to lack of visual feedback, all participants received one trial of visual feedback for every 20 trials. Normalized tracking error was computed for all participants to evaluate their ability to trace the circle before and after training both with and without visual feedback. RESULTS We found that participants who practiced the motor skill with haptic guidance from the robot learned to a greater extent (tracking error without visual feedback: 95.1 ± 9.6% to 53.6 ± 6.2%; p < 0.001) than those who did not receive haptic guidance (tracking error without visual feedback: 79.4 ± 9.2% to 76.4 ± 8.2%; p = 0.746) and also performed better at post-test (53.6 ± 6.2% vs. 76.4 ± 8.2%; p = 0.041). CONCLUSIONS These findings indicate that haptic guidance from rehabilitation robots can be used to facilitate motor learning. Further, this finding highlights that it may be important to separate out more powerful sources of feedback, such as visual feedback, to detect the effects of haptic guidance.

O14.7 Short latency stretch reflexes depend on the balance of activity in agonist and antagonist muscles during ballistic elbow movements

Zoe Villamar[1], Daniel Ludvig[1], Eric Perreault[1]
[1]*Northwestern University; Shirley Ryan AbilityLab*

BACKGROUND AND AIM: The spinal stretch reflex is a fundamental building block of motor function, modulating sensitivity across tasks to augment volitional control. Stretch reflex sensitivity can vary continuously during movement and changes between movement and posture. While there have been many demonstrations of reflex modulation and investigations of the underlying mechanisms, there have been few attempts to provide simple, quantitative descriptions of the relationship between the volitional control and stretch reflex sensitivity during tasks that require the coordinated activity of several muscles. Here we develop such a description and use it to test the hypothesis that the modulation of stretch reflex sensitivity during movement can be explained by the balance of activity within the relevant agonist and antagonist muscles better than by the activity only in the muscle homonymous with the elicited reflex. METHODS: We applied continuous pseudo-random perturbations of elbow angle as subjects (N = 17) completed approximately 500 movements in elbow flexion and extension. Measurements were averaged across the repeated movements to obtain continuous estimates of stretch reflex amplitude and background muscle activity from electromyograms of the brachioradialis (BRD), biceps brachii, triceps long head, and triceps lateral head (TRILAT). We also ran a control experiment on a subset of subjects (N = 4) performing postural control tasks at muscle activity levels matched to those of the movement task. For both experiments, we assessed the relationship between background activity in the agonist and antagonist muscles controlling elbow movement and the stretch reflexes elicited in them. RESULTS: Modulation in the stretch reflexes during movement was described well by the modulation of background activity in the agonist and antagonist muscles. Models incorporating agonists and antagonists were significantly better than those considering only agonists to the muscle in which the reflex was measured (agonists only: R² = 0.69±0.05; agonists + antagonists: R² = 0.86±0.04; p<0.001). Reflex magnitudes increased with increasing background activity in the agonists and decreased with increasing activity in the antagonists. Gains were similar for agonists and antagonists, thereby representing balanced reciprocal modulation (Figure 1A). This balance was not present during the postural task, in which the stretch reflex was much more sensitive to activity in the agonists than the antagonists (Figure 1B). CONCLUSIONS: We found that the changes in reflex sensitivity during movement were best explained by the balance of activity in the agonists and antagonists controlling movement, which was different than the postural task in which reflex sensitivity was mainly due to the background activity of the homonymous muscle. These results describe the heightened reciprocal control of stretch reflexes during movement.

Oral 15 - Biomechanics

O15.1 Evolution of neuromechanical, physiological and clinical changes throughout pregnancy: a prospective cohort study

Catherine Daneau[1], François Nougarou[1], Stephanie-May Ruchat[1], Martin Descarreaux[1]
[1]*Université du Québec à Trois-Rivières (UQTR)*

BACKGROUND AND AIM: Approximately 50% of women will experience lumbopelvic pain during pregnancy. Increased estrogen and progesterone levels contribute to ligament laxity in the pelvic girdle, potentially leading to joint instability and predisposing pregnant women to lumbopelvic pain. The flexion-relaxation phenomenon, defined as a silencing of myoelectric activity during a full trunk flexion, has been used to evaluate neuromuscular adaptations since silencing of myoelectric activity is lacking in individuals with low back pain. Although hormonal changes might be involved in lumbopelvic joint instability causing pain in pregnant women, their influence is not yet clearly established. To investigate neuromechanical, physiological and clinical changes and their association during pregnancy. METHODS: Twenty-eight pregnant women completed, throughout pregnancy, clinical questionnaires to assess functional disability, risk of poor prognosis, avoidance behaviors, catastrophizing and pain, and realized a flexion-relaxation task. Blood samples were taken at each trimester to assess the levels of estrogen and progesterone. Flexion-relaxation was assessed using surface electromyography over the right and left lumbar paraspinal muscles. Lumbar and pelvic angles during the task were also collected using a motion capture system. RESULTS: Estrogen and progesterone levels significantly increased throughout pregnancy. Weekly nocturnal and diurnal lumbopelvic pain significantly increased between the first two trimesters and the third one. Between the first trimester and the two last ones, functional disability significantly increased whereas catastrophism decreased. The risk of poor prognosis also significantly increased between the first and third trimester. Between trimesters one and two, significant correlations were observed between estrogen and pain before (r = -0.52) and after (r = -0.49) the task as well as functional disability (r = 0.47). No correlation was observed between hormonal levels and neuromechanical variables. Between trimesters two and three, a positive significative correlation was observed between progesterone and pain after the task (r = 0.50). No correlation was observed for all the other variables except between estrogen and muscle activity during trunk extension during the task (r = 0.53). CONCLUSIONS: Our result showed low to moderate correlations between pregnancy hormone levels and back pain related outcomes during pregnancy, but very little correlation to neuromechanical changes. Estrogen and progesterone have higher concentrations towards the end of pregnancy while relaxin reaches its highest level during the 15th week of pregnancy. This hormone may have a greater impact on back pain related outcomes and neuromechanical variables throughout pregnancy.

O15.2 Contribution of Shear Wave Elastography to better Characterization of Skeletal Muscles in vivo

Filiz Ates[1], Manuela Zimmer[1], Benedict Kleister[2], Justus Marquetand[2]
[1]University of Stuttgart, [2]University of Tuebingen

Background and Aim: Mechanical characterization of skeletal muscles in vivo is a key for better understanding movement and performance alterations due to exercise, aging, or neuromuscular diseases. Since non-invasive force measurements are hardly feasible in vivo, surface electromyography (sEMG) has been widely used for muscle force estimation. However additional to many other limitations, sEMG lacks information on resting muscle. Previously, the elastic modulus of muscles attained using shear wave elastography (SWE) was shown to represent muscle mechanics in both passive [1] and active [2] states. Though, relating muscle stiffness to its length and in vivo position is not straight forward. Presently, we investigated the biceps brachii muscle (BB) with respect to elbow joint position and function and tested the hypotheses that SWE can detect the changes in BB mechanics (i) in passive state for different muscle lengths, (ii) during isometric ramp contractions at different activity levels. Methods: SWE, sEMG of BB and isometric elbow torque were measured simultaneously from 14 young volunteers (7 females, 28.1 ± 5.1 years, 77.2 ± 17.4 kg, 177.7 ± 7.5 cm). At five elbow angles (60°-180°), a passive trial, three maximum voluntary contractions (MVC) and nine isometric ramp contractions (up to 25%, 50%, 75% of MVC torque) were performed. Elastic modulus was deduced from SWE and root-mean squared amplitude (RMS) was calculated from sEMG. sEMG RMS/torque and elastic modulus/torque relationships were fitted to a linear model and coefficients of determination (R2) were calculated. Results: At passive state, elastic modulus changed between 60° (11.8 ± 3.5 kPa) and 150°/180°, 90° (16.8 ± 7.0 kPa) and 150°/180° (26.0 ± 7.1 / 35.8 ± 8.0 kPa) elbow angles ($P<0.05$). At MVC, the elbow torque (51.2 ± 19.5 Nm at 60°) decreased with the increasing elbow angle (26.1 ± 13.8 Nm at 180°). The elastic modulus and sEMG RMS did not show significant dif-ferences between elbow angles. During ramp contractions, the elastic modulus reflected the major changes both due to activity levels and joint positions. sEMG RMS on the other hand showed significant differences only for activity levels. Linear regression of sEMG RMS over torque revealed good agreement for all angles tested. However, elastic modulus did not follow a linear relationship at extended joint positions (e.g. 150°, Figure 1). Conclusions: The present findings support the hypotheses posed and indicated that SWE can be used to characterize both active and passive mechanical properties of muscles. We found that even though normalized sEMG represents muscle activity, it cannot solely explain muscle's contribution to joint function at longer muscle lengths. Consequently, SWE providing more realistic results might be a promising new modality for detecting muscular changes due to exercise or pathological alterations in the course of neuromuscular diseases. Acknowledgement: Funded by the Deutsche Forschungsgemeinschaft (DFG - German Research Foundation) GRK 2198 - 277536708. References: [1] Ates F. et al. 2018, Eur J Appl Physiol, 118: 585-593. [2] Ates F. et al. 2015, J Electromyog Kinesiol, 25: 703-708.

O15.3 Normal variability of common orthopaedic morphology-based metrics of the patellofemoral joint: a dynamic CT imaging study on healthy subjects

Luca Buzzatti[1], Benyameen Keelson[2], Jona Van den Broeck[2], Thierry Scheerlinck[3], Gert Van Gompel[3], Jean-Pierre Baeyens[2], Michel De Maeseneer[3], Johan De Mey[3], Jef Vandemeulebroucke[2], Savanah Hereus[2], Nico Buls[3], Erik Cattrysse[2]
[1]Vrije Universiteit Brussel (VUB), [2]Vrije Universiteit Brussel, [3]Universitair Ziekenhuis Brussel (UZ Brussel)

BACKGROUND AND AIM Dynamic CT images have been considered to evaluate knee joint kinematics of subjects suffering from patellar instability. However, the movements performed have always been in a non-weight-bearing setting, which may differ from real-life weight bearing. Therefore, a device that allows weight-bearing dynamic CT acquisition with the patient in a supine position was developed. The aim of this study was to provide clinicians with a healthy reference dataset of three knee kinematic metrics acquired during dynamic CT imaging in a loading condition. METHODS Twenty-one healthy adults (42 knees) volunteered for this study. This study was approved by Ethics Committee and written informed consent was obtained. A novel weight-bearing device, similar to a leg press, was used in order to simulate constant gravitational force during horizontal dynamic CT acquisition. The device had a platform to position the feet, a moving component to support the body and a loading system, which provided the required constant resistance. The subject performed consecutive flexion-extension cycles in a horizontal squat like position. A dynamic scan protocol (80kvp, 50mA, 6.7s) was performed using a 256-slice wide beam CT to acquire images of both knees at the same time, while the subject was performing the flexion-extension task. By means of automatic multi-atlas segmentation and rigid registration approach, a transformation matrix was computed for each time point for each single bone (Tibia, Femur and Patella). Six bony landmarks were selected from the CT image with the knee in full extension to compute three orthopaedic kinematic metrics for each time point: tibia-tuberosity trochlear groove (TTTG-mm), bisect offset (BO-%), lateral patellar tilt (LPT-degrees). All metrics were computed between 0˚ and 30˚ of knee flexion motion. RESULTS In the first 30° of flexion, all the calculated metrics presented a decreasing trend (Figure 1a). TTTG, BO and LPT had an average value of 12.9 mm, 69.0% and 12.6° at 0° flexion, respectively. Between full extension and 30˚ flexion, TTTG, BO and LPT had a gradual change up to 7mm (95%CI: 6.3-7.7), 11.9% (95%CI: 9.3-14.5) and 4.4˚ (95%CI: 3.3-5.4) respectively. No difference was shown between the eccentric and concentric phases. Our results differed from previous publications that used dynamic CT in an unloaded knee motion condition (Figure 1b). Our healthy subjects showed lower values compared to symptomatic knees and to contralateral asymptomatic knees. Moreover, in contrast to previous studies, our results represent kinematic data on a weight-bearing condition which may be more representative of a physiological movement of the knee. CONCLUSIONS Information from weight-bearing dynamic CT imaging of healthy subjects can be of potential help to determine normal variability and might help orthopaedic surgeons to decide if an intervention is indicated or has been successful to restore normal kinematics.

O15.4 The relationship between pain catastrophizing, pain sensitivity, and inter-joint coordination during a lifting task in people with chronic low back pain.

Patrick Ippersiel[1], Richard Preuss[1], Timothy Wideman[1], Shawn Robbins[1]
[1]McGill University

BACKGROUND AND AIM: Pain may serve as a protective mechanism, prompting guarding of a region that is perceived to be injured or threatened [1]. Tighter inter-joint coordination and reduced movement variability reflect guarded movement in people with low back pain (LBP). While these

behaviors are thought to increase tissue loading and complicate recovery, it is unclear why these behaviors persist in people with chronic LBP. Despite calls for conceptualizing movement within a biopsychosocial framework, key risk factors for disability such as heightened pain catastrophizing and pain sensitivity are often considered independent from biomechanical metrics - leaving our understanding of movement somewhat limited. Therefore, we aimed to determine if pain catastrophizing and pain sensitivity were related to guarded movement (via joint coordination and variability) during a lifting task in people with chronic LBP. METHODS: Fifty-four adults with chronic non-specific LBP (>3 months) were recruited (36F, mean age=44.4, SD=10.5). Baseline demographics, pain (Brief Pain Inventory), and pain catastrophizing (Pain Catastrophizing Scale) were measured. Pain sensitivity was quantified via temporal summation of pain and pressure pain thresholds at the lumbar spine. Participants performed a crate lifting task (partitioned into lifting and replacing phases), while a motion capture system collected spinal kinematics. Hip and lower lumbar (LowLx) joint angles were extracted, and continuous relative phase analysis quantified (i) coordination amplitude (via mean absolute relative phase) and (ii) coordinative variability (via deviation phase) for the Hip-LowLx joint pair [2]. Linear regression analyses tested the hypotheses that (i) pain catastrophizing and (ii) pain sensitivity were associated with Hip-LowLx coordination and coordinative variability, after accounting for other factors. RESULTS: For Hip-LowLx coordination amplitude, the base model (age, sex, BMI, pain severity) was statistically significant for crate lifting (R^2=0.192, p=0.044) and replacing (R^2=0.219, p=0.023) phases. Adding pain catastrophizing improved our model for lifting (R^2=0.323, p=0.003; b=-1.46, p=0.006, ΔR^2=0.130) and replacing (R^2=0.331, p=0.003; b=-1.43, p=0.010, ΔR^2=0.112) phases, showing that greater pain catastrophizing was related to more in-phase, or guarded movement. Adding temporal summation of pain and pressure pain thresholds in a separate step did not improve our models. For Hip-LowLx variability, no models were statistically significant. DISCUSSION: Pain catastrophizing was related to more in-phase Hip-LowLx coordination (i.e., guarding) during a lifting task, while measures of pain sensitivity were not. Hip-LowLx variability was largely unrelated to pain catastrophizing and pain sensitivity. This suggests that psychological factors and certain movement behaviors are intertwined - to some degree - and that different metrics of movement may show distinct relationships with biopsychosocial variables. REFERENCES [1]:Hodges P; Clin J Pain. 2015 Feb;31(2):97-107. [2]:Lamb P; Clin Biomech (Bristol, Avon). 2014 May;29(5):484-93.

O15.5 A subject-specific musculoskeletal model of the spine for estimating lumbar internal forces and stability: its convergent validity with local dynamic stability measures

Amirhossein Eskandari[1], Farshid Ghezelbash[1], Aboulfazl Shirazi-Adl[1], Christian Larivière[1]
[1]IRSST

BACKGROUND AND AIM: Assessment of spine stability is critical despite numerous interpretations and confusion in its definition. Two distinct approaches to quantify the spine stability exploit 1- musculoskeletal (MS) models to estimate the structural stability 2- nonlinear dynamic methods for the local dynamic stability. The aim of this study is to test the convergent validity of the structural approach, using the local dynamical stability as a theoretically related construct. METHODS: Thirty-two subjects performed repetitive lifts (35 cycles) with and without load (4 and 2.6-Kg crates for males and females) while total body kinematic data were recorded using inertial motion units. A dynamic and subject-specific (spine profile, musculature, mass, height, joint stiffness) kinematic-optimization-driven MS model was developed to quantify spinal load and structural stability. All model outcomes were averaged over the cycles for each of the 6 snapshots (up, middle, and down snapshots of the lifting and lowering phases). Then, minimum, maximum, and average scores (across the 6 snapshots) of different stability measures, namely critical q (CQ: critical dimensionless stiffness gain at which spine becomes unstable), min eigenvalue of the Hessian matrix, and L4/L5 sagittal rotational stiffness were calculated. Local dynamic stability of the trunk was estimated using 1- short and long max Lyapunov exponent (LyE) and, 2- mean and max Floquet multipliers (FM) computed across the cycle. RESULTS: One-way ANOVAs determined that mean and max FM measures increased insignificantly (by 5.8% and 3.7%) as load increased, whereas short and long LyE remained unchanged. Most of the MS model stability outcomes were not affected significantly by the load except the min CQ and max L4L5 rotational stiffness. No correlation reached statistical significance ($P < 0.05$) in the load condition. In the no-load condition, moderate correlations were reached between short-LyE and different structural stability outcomes (max EigVal: 0.51; min CQ: -0.53; L4L5 stiffness: 0.51 to 0.63). CONCLUSIONS: Structural and local dynamic spine stability estimates shared small to moderate common variance, which support convergent validity to the MS model to some degree, at least in the no-load condition. However, further model development is needed, especially electromyography inputs to drive the MS model which may result in different findings. Larger hand loads similar to those expected in manual material handling activities may influence the conclusions of this study.

O15.6 Lower-limb joint-coordination and coordination variability during gait in children with cerebral palsy.

Cloé Dussault-Picard[1], Patrick Ippersiel[2], Philippe Dixon[1]
[1]University of Montreal, [2]McGill University

Background & Aim: Children with cerebral palsy have poor motor control, which alters their ability to perform tasks such as walking. Continuous relative phase analysis is commonly used to quantify motor control impairments via inter-joint coordination and coordination variability; however, it has not been applied to gait analysis in children with cerebral palsy. This study aims to (1) compare inter-joint coordination and inter-joint coordinative variability patterns during walking in children with cerebral palsy to their typically developing peers via continuous relative phase analysis and (2) explore how inter-joint coordination and coordination variability are related to gait deviations in children with cerebral palsy. Methods: 45 children with cerebral palsy and 45 typically developing children walked equipped with retroreflective markers. Continuous relative phase analysis for knee-hip and ankle-knee joint pairs quantified inter-joint coordination and coordination variability. The Gait Profile Score provided overall gait deviations. Group differences were assessed with unpaired t-tests for coordination amplitude and variability (knee-hip, ankle-knee) across gait events. For the cerebral palsy group, correlations assessed the relation between the Gait Profile Score and coordination metrics. Results: The cerebral palsy group showed more in-phase patterns for knee-hip coupling compared to the typically developing group (initial contact, loading response, mid-stance, terminal swing) ($p \leq 0.03$). The cerebral palsy group showed lower knee-hip coordination variability (mid-stance, mid-swing) ($p \leq 0.037$) and lower ankle-knee coordination variability (initial contact, loading response, terminal swing) ($p < 0.001$). The Gait Profile Score correlated negatively ($r = [0.323\text{-}0.472]$: weak to moderate correlation) with the knee-hip inter-joint coordination (initial contact, loading response, mid-stance, terminal swing) ($p \leq 0.042$). Conclusion: Children with cerebral palsy showed a more cautious in-phase gait strategy during challenging transitional gait cycle phases (beginning and end) and less flexible and adaptable motor behaviors. Moreover, the correlation between in-phase joint patterns and increased gait deviations

(Gait Profile Score) reinforces the relevance of coordination analysis to assess motor control impairment.

O15.7 Reliability and minimal detectable change of ankle impedance parameters in standing and walking

Luis Cubillos[1], Elliott Rouse[1], Varun Joshi[1], Chandramouli Krishnan[1]
[1]*University of Michigan*

BACKGROUND AND AIM: Neurological injuries, such as stroke and spinal cord injury, often cause gait impairments. Commonly used clinical assessment tools, while useful for documenting patient progress, lack objectivity and are largely qualitative. Moreover, these tools only enable evaluation of the external changes that underlie patient symptoms and cannot provide insight into the internal changes that cause these symptoms. These internal properties, termed mechanical impedance, are fundamental mechanical descriptions that govern movements of the body and can be quantified by characterizing the dynamic relationship between the torques and motions of a joint during a perturbation. However, before using these tools clinically, the reliability of these measurements must be established. In this study, we characterize the test-retest reliability of ankle impedance parameters (i.e., stiffness, viscosity, and inertia) in quiet standing and in the stance phase of walking. METHODS: Eighteen young able-bodied individuals volunteered to participate in this study. Participants were tested on two different days that were separated by at least one day (M = 6.2 days, SD = 5.3). During each testing session, participants received several small ankle dorsiflexion perturbations (constant velocity ramp; amplitude: 2 deg; duration: 75ms; velocity: 45.8 deg/s; max accel: 1800 deg/s^2) in standing and during the stance phase of walking using a custom-designed robotic platform. Mechanical impedance of the ankle joint was quantified by computing participant-specific ensemble averages of changes in ankle angle and torque due to the perturbation and fitting a second-order dynamic model parameterized by ankle stiffness, viscosity, and inertia. The test-retest reliability of these impedance parameters was assessed using intraclass correlation coefficients (ICCs). ICC analysis was performed using a two-way mixed-effects model for single measurement and absolute agreement [i.e., ICC (3,1) model], and the resulting ICC values were interpreted as follows: Poor (<0.40), Fair (0.40-0.59), Good (0.60-0.74), and Excellent (0.75-1.00). The minimal detectable change (MDC) for each of the impedance parameters was also computed to establish the smallest amount of change that can be deemed as a true change for a participant between two-time points. RESULTS: In standing, the reliability of stiffness (ICC = 0.83) and inertia (ICC = 0.85) was excellent, and viscosity was good (ICC = 0.73). The MDC for stiffness, viscosity, and inertia was 0.81 Nm/rad/kg, 0.01Nms/rad/kg, and 0.01 kgm^2/rad, respectively. During walking, the reliability of stiffness (ICC = 0.80) and viscosity (ICC = 0.78) were excellent, and inertia was fair (ICC = 0.47). The MDC for stiffness, viscosity, and inertia were 1.38 Nm/rad/kg, 0.01Nms/rad/kg, and 0.02 kgm^2/rad, respectively. CONCLUSIONS: The results indicate that the reliability of impedance parameters is generally good and can be used clinically to estimate ankle joint impedance during standing and walking. Future studies on patient populations are required to determine if the results are generalizable to a broader population.

Oral 16 – Aging and Neuromuscular Imaging

O16.1 Shoulder muscle activity is less directionally specific in older compared to younger adults: a potential contributor to age-related shoulder weakness

Emma Baillargeon[1], Daniel Ludvig[2], Amee Seitz[2], Constantine Nicolozakes[2], Margaret Coats-Thomas[2], Eric

Perreault[2]
[1]University of Pittsburgh, [2]Northwestern University

BACKGROUND AND AIM: Many older adults struggle with daily tasks due to shoulder pain or weakness, yet how shoulder muscle activity differs with age is not well understood. Prior studies either cannot distinguish the effect of age from pathology or include only a small subset of muscles. No study has assessed the impact of age on rotator cuff muscle activity. Our aim was to test if shoulder muscle activity differs with age in those without shoulder pain or pathology to quantify the effect of age independent of impairment. METHODS: Right-handed younger (8F/6M, 27.2±5.6 years), middle-aged (5F/5M, 51.8±2.7 years), and older adults (4F/4M, 71.5±9.5 years) with pain-free shoulder and cervical spine range of motion participated. Those with shoulder pain, injury, or full-thickness biceps or rotator cuff tendon tears were excluded to minimize potential confounding factors. Muscle activity and torque data were collected with participants' right arm casted to a 6-DOF loadcell in 90° shoulder abduction and elbow flexion. We recorded electromyograms (EMGs) as participants held 3D isometric shoulder torque targets for 3 seconds at 10% and 20% of their maximum voluntary torque in 26 directions (order randomized). We used fine-wire EMGs to record the supraspinatus, infraspinatus, and subscapularis rotator cuff muscles which lie deep to superficial muscles. Twelve additional muscles were recorded with surface EMGs. We analyzed the impact of age on the mean, rectified EMG amplitude (notch filtered 60Hz, bandpass filtered 20-500Hz for surface or 20-1500Hz for fine-wire, MVC normalized) using a linear mixed-effects model (continuous factor: age; fixed factors: muscle, target level, target direction; random factor: participant). Data were also modeled with age as a categorical variable for visualization (Fig 1). RESULTS: Shoulder muscle activity differed with age. The effect of age varied across muscles but in all cases resulted in more uniform muscle activity across torque directions. Muscles primarily active during arm elevation (5 of the 15 recordings) increased uniformity through increased age-dependent activity all directions (Fig 1A). Five muscles primarily active when pushing down and back increased uniformity by an age-dependent decrease in muscle activity in directions where they were most active in younger adults (Fig 2B). Finally, pectoralis major and middle trapezius muscle activity was increased with age in directions with low activity in younger adults (Fig 1C). Age-dependent differences in biceps and triceps activity did not match the patterns above; upper trapezius activity did not differ with age. CONCLUSIONS: Reduced directional specificity of muscle activity is consistent with increased co-contraction and may contribute to the shoulder weakness seen in older adults. Age-related differences in muscle activity could also contribute to shoulder pathology via altered joint loading. Future studies are needed to determine how age-related differences develop over time and their relationship with pain, pathology, or dysfunction.

O16.2 Age- and Sex-specific Effects in Paravertebral Surface Electromyographic Back Extensor Muscle Fatigue in Chronic Low Back Pain Recorded during Submaximal Cyclic Back Extension Exercises

Gerold Ebenbichler[1], Richard Habenicht[2], Josef Kollmitzer[3], Patrick Mair[4], Paolo Bonato[5], Peter Blohm[2], Thomas Kienbacher[2]
[1]Vienna Medical University, [2]Karl-Landsteiner-Institute for Outpatient Rehabilitation Research, [3]TGM - School of Engineering, [4]Harvard University, [5]Spaulding Rehabilitation Hospital

Background: We recently found the fatigue-related frequency content of the surface electromyogram (MF-SEMG) recorded during cyclic back extension exercises and intended to minimize an increased risk of back injury particularly in training-inexperienced older test persons to reliably differentiate between

younger and older healthy individuals. Such observations suggest the SEMG fatigue method to early detect aging back muscles antecedent to sarcopenia in a population at large. As the impact of aging on back muscles may hold clues to both normal aging and low back pain, it remains uncertain, whether or not this method would also discriminate between younger and older persons with low back pain. Aims: This research sought to investigate whether or not the instantaneous MF-SEMG fatigue (IMDF-SEMG) recorded from cyclic back extension exercise would differentiate back muscle function between younger and older male and female individuals with cLBP. Methods: Seated on a back dynamometer a total of 211 persons with cLBP performed a series of three maximal voluntary isometric back extensions (MVC), followed by an isometric back extension at 80% MVC, and after a break 25 slow cyclic back extensions loaded 50% MVC. SEMG data was recorded bilaterally at L1, , and L5 (multifidus) L2 longissimus and L1 (iliocostalis lumborum) muscle sites. Tests were repeated two days and six weeks later. A linear mixed-effects model with fixed effects ?age, sex, test number? and the random effect ?person? tested for age-specific differences in both the initial value and the time-course (as defined by the slope of the regression line) of the IMDF-SEMG values calculated for the shortening phases of the exercise cycles. Generalizability Theory served to examine reliability of the EMG measures. Results: Back extensor strength was comparable in younger and older adults. Perceived back muscle fatigue at the end of the test was moderate in all groups. The IMDF-SEMG time-course showed more rapid changes in younger than in older individuals, particularly in males. 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 reliability levels. Conclusions: Like in healthy, pain-free individuals, the IDMF-SEMG fatigue method proofed successful to reliably distinguish back muscle function in younger from older men and to a lesser extent also in women with cLBP, if a moderately demanding cyclic exercise test protocol was used. These findings encourage to further develop this measure into a screening test intended to early detect aging back muscles antecedent to sarcopenia in a population at large.

O16.3 Age-related decreases in ankle impedance are associated with a decrease in reflex activity

Kristen Jakubowski[1], Daniel Ludvig[1], Sabrina Lee[2], Eric Perreault[1]
[1]Northwestern University, [2]Simon Fraser University

BACKGROUND AND AIM: Healthy aging is associated with a decreased ability to maintain balance when perturbed. Ankle impedance is essential for maintaining balance as it is the joint's resistance to an imposed movement. However, it is currently unknown how aging impacts ankle impedance. Ankle impedance arises from an intrinsic component originating from the tissues that span the joint; and a reflexive component from the burst of muscle activity following a stretch of the muscle. With aging, there are changes to stretch reflexes, which could decrease the reflexive component of ankle impedance and thereby impair the response to postural disturbances. Therefore, the goal of this study was to determine how aging impacts ankle impedance and to test the hypothesis that age-dependent changes in impedance are related to changes in the stretch reflex. METHODS: Seventeen healthy young (27 ± 3 years) and nine healthy older adults (73 ± 6) were seated with their right foot rigidly attached to a rotary motor with their ankle positioned at 90 degrees. Participants performed isometric plantarflexion contractions from 0% to 30% of their maximum voluntary contraction. Small, stochastic perturbations were applied to the ankle to elicit stretch reflexes and enable system identification of ankle impedance. Stiffness, the static component of impedance, is presented here due to its relevance to postural stability.

Surface electromyograms were recorded from the tibialis anterior, medial gastrocnemius, lateral gastrocnemius, and soleus. Short-latency reflex magnitude was quantified by the average activity 20ms after reflex onset; background activity was quantified in the window 0-40ms before each perturbation. We quantified the magnitude of the reflex by the gain scaling factor, computed as the slope of the relationship between background activity and the short-latency reflex. RESULTS: For both young and older adults, ankle stiffness increased as plantarflexion torque increased (Fig 1A). Ankle stiffness was not significantly different between young and older adults (p > 0.1). While group differences were not observed, a subset of older adults exhibited lower ankle stiffness (Fig 1B, n = 5). We sought to determine what could be contributing to this decrease. Older adults had significantly smaller short-latency reflexes in the medial gastrocnemius and soleus compared with young adults (both p < 0.05). We found that older adults who exhibited a lower gain scaling factor also had lower ankle stiffness (Fig 1B). The lower reflex response may indicate a decrease in the reflexive contribution to ankle stiffness. CONCLUSIONS: The decrease in triceps surae stretch reflexes in this subset of older adults could be contributing to the decrease in ankle stiffness. A reduction in ankle stiffness may impair their ability to respond to postural disturbances. Given that individuals can volitionally control reflexes, our findings may aid in developing subject-specific training protocols to improve balance.

O16.4 Child-adult differences in motor-unit activation strategy during submaximal wrist flexion - preliminary findings

Stacey Woods[1], Andrew McKiel[1], Trent Herda[2], Raffy Dotan[1], Panagiota Klentrou[1], Michael Holmes[1], David Gabriel[1], Bareket Falk[1]
[1]Brock University, [2]University of Kansas

BACKGROUND & AIM: Few studies have used surface electromyography (sEMG) decomposition to explore the neuromuscular mechanisms underlying child-adult differences in muscle performance, with mixed results. Conflicting results may be due to the evaluation of different muscles or contraction intensities. Thus, our purpose was to examine differences in discrete motor-unit (MU) activation of the flexor carpi radialis between boys and men during submaximal contractions at low and high intensities. METHODS: Following the determination of maximal voluntary wrist flexion (MVC), 11 boys (9.6±1.6yrs) and 11 men (25.2±2.2yrs) completed trapezoidal contractions, twice each, at 25 and 70% MVC. sEMG was captured by a Delsys Trigno Galileo sensor and NeuroMap algorithms were used to decompose sEMG into individual MU action potential (MUAP) trains. MUAP amplitude (MUAPamp), recruitment threshold (RT), and MU firing rates (MUFR) were calculated from the most stable 3- and 5-s of the 70 and 25% MVC force traces, respectively. Slopes and y-intercepts were extracted from the linear MUAPamp-RT and MUFR-RT relationships, while the A and B terms were used to describe the exponential MUFR-MUAPamp relationship. Group differences in MVC were assessed using an ANCOVA, and independent t-tests were used to assess differences among MU variables. RESULTS: Wrist flexion MVC was significantly higher for men (191.9±43.6N) than boys (80.7±19.2N), even after considering differences in wrist flexors' size (p<0.001). The slope and y-intercepts of the MUAPamp-RT and MUFR-RT relationships were generally similar in boys and men at both contraction intensities (p=0.12-0.95), except for significantly lower y-intercept in the MUFR-RT relationship for boys (25.0±5.4pps) compared with men (31.7±3.7pps) during the 70% MVC (p<0.01). In both groups, A and B terms of the MUFR-MUAPamp relationship (coefficient and exponent, respectively) were higher in 70% MVC (y=48.3e^{-11.7} and 50.6e^{-7.2}) than in 25% MVC (y=30.7e^{-24.5} and 35.4e^{-27.0}), in the boys and men, respectively (p<0.01). The relative change in the B-term from 25 to

70% MVC was significantly greater (i.e., the slope became less steep) in men (71.9±10.5%) than boys (52.9±17.2%; $p<0.01$). The opposite pattern (NS) was observed in the A term, with a larger relative increase for boys than men (76.1±75.4 vs. 44.7±34.3%; respectively $p=0.23$). CONCLUSIONS: With increasing contraction intensity, the relative MUAPamp increase was not different in men and boys. Relative changes in the MUFR-MUAPamp relationships from 25 to 70% MVC indicate that relative MUFR increase of moderate to large MUs was greater in men, whereas in the boys, MUFR rose more in the smaller MUs. These findings suggest that during high-intensity submaximal contractions of the wrist flexors boys activate their higher-threshold MU's to a lesser extent than men. Consequently, in order to achieve the same relative high-intensity force, boys increase the MUFR of low-threshold MUs to a greater extent.

O16.5 Quantifying muscle size (a)symmetry in adolescent idiopathic scoliosis

Phoebe Duncombe[1], Maria Antico[2], Maree Izatt[2], Paige Little[2], Peter Pivonka[2], Andrew Claus[3], Kylie Tucker[1]

[1]The University of Queensland, [2]Queensland University of Technology, [3]The University of Queensland/Royal Brisbane and Women's Hospital

BACKGROUND AND AIM: Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional bony deformity of the spine that occurs between the ages of 10 to 18 years and is associated morphological and physiological changes in paraspinal muscles. An asymmetry in paraspinal muscle size may apply asymmetrical forces to the growing spine and facilitate asymmetrical growth. We aim to provide insight into the potential role of muscle force asymmetries in the presence and progression of AIS. Magnetic resonance images (MRIs) were collected from 44 female participants who attended the Queensland Children's Hospital Spine Deformity Clinic between 8/2012 and 10/2017. Twenty-two adolescent participants had right thoracic scoliotic curves; Cobb's curve angle: 29±9º; age: 12.6±1.4 years; adjusted height:150±11cm; Risser Grade for skeletal maturity: 0-2. A further 22 participants were matched controls with age: 12.5±1.4 years; height: 152±10cm; Risser Grade: 1-4. METHODS: Superficial (iliocostalis and longissimus) and deep (multifidus, semispinalis and rotatores muscles) paraspinal muscle cross-sectional areas (CSA; mm^2) were determined by manually delineating muscle boundaries (Fig 1A). CSAs of consecutive slices, from the upper to the lower vertebral body boundaries, were multiplied by MRI slice thickness (0.5mm) and summed, to calculate the muscle volume (mm^3) associated with individual vertebral segments (Fig 1B). A muscle volume asymmetry index [Ln(concave/convex volume)], was determined for the level of the curve apex and lower-end vertebral (LEV: the most tilted vertebra below the apex) of the scoliotic curve, or the matched vertebral level of the control group. Of the participants with AIS, data from 14 participants (Cobb's angle: 29±9°; age: 14.2±1.5 years, adjusted height: 158±9cm, Risser Grade: 0-2) were also available at 13.7±3.8 months after starting bracing treatment and were used to determine the effect of bracing on muscle asymmetry indices. RESULTS: Asymmetries in superficial muscle volumes at the apex and the LEV, as well deep muscles at LEV were not different between the AIS and the control group. Deep paraspinal muscle volumes at the level of the curve apex were 15±21% greater on the concave compared to convex side of the AIS group, which was significantly ($p<0.05$) larger than the asymmetry for the control group -7±3% (Fig 1C). The asymmetry in AIS participants was positively correlated with Risser grade ($r=0.55$, $p<0.05$) and Cobb's angle ($r=0.51$, $p<0.05$), but not chronological age ($r=0.39$, $p>0.05$). There was no change in the asymmetry index of deep or superficial muscles at the apex or LEV levels with bracing (all $p>0.05$). CONCLUSIONS: This work highlights that the asymmetry in the AIS participants' deep apical muscles lies outside the typical asymmetry range observed in adolescents with symmetrical spines and may play a role in the pathogenesis of AIS. The lack of change in asymmetry with bracing highlights that bracing may not influence the asymmetry of the paraspinal muscles. Further investigation into the role of the paraspinal musculature in the development of different scoliotic curve types is needed.

O16.6 Morphological changes of deep extensor neck muscles in relation to the maximum level of Compression and canal compromise in patients with degenerative cervical myelopathy

Neda Naghdi[1], James Elliott[2], Michael Weber[3], Michael Fehlings[4], Maryse Fortin[5]
[1]Concordia University, [2]University of Sydney, [3]McGill University Health Centre, [4]University of Toronto, [5]Concordia

BACKGROUND AND AIM: Degenerative cervical myelopathy (DCM) is characterized by a narrowing of the cervical spinal canal, leading to pain and neurological impairments. The deep extensor neck muscles, especially the cervical multifidus (MF) and semispinalis cervicis (Scer), are often impaired in patients with cervical disorders. This study aimed to examine the relationship between morphological changes of the deep extensor neck muscles in patients with degenerative cervical myelopathy (DCM) and the level of maximum spinal compression and canal compromise. METHODS: A total of 171 patients from a Prospective DCM-International cohort study database were included in this study. Total cross-sectional area (CSA) (Figure 1), functional CSA (fat free area, FCSA), ratio of FCSA/CSA (fatty infiltration) and asymmetry of the MF+SCer together, and deep extensor muscles as a group (e.g., MF, SCer, semispinalis capitis, splenius capitis) were obtained bilaterally from axial T2-weighted MR images at mid-disc, at the level of maximum cord compression and the level below. The level and degree maximum spinal cord compression (MSCC) and maximum canal compromise (MCC) was determined using the following formulas MSCC= [1 −di (da + db)/ 2] × 100, and MCC = [1 −Di (Da + Db)/ 2] × 100 as defined by Fehlings. The FCSA was measured using a highly reliable thresholding technique described in a previous study, and the relative percent asymmetry in CSA, FCSA and FCSA/CSA was calculated using: [(L − S)/L] x100, where L is the larger side, and S is the smaller side. The relationship between the muscle parameters of interest, MSCC and MCC was assessed using multivariate linear regression models, adjusting for age, body mass index (BMI) and sex. Separate models were used for each muscle group and spinal level. RESULTS: The average MSCC and MCC was 42.8417.7% and 45.3814.96%, respectively. Greater MF+Scer fatty infiltration (e.g., lower FCSA/CSA) was associated with greater MCC (P= 0.032) and MSCC (p=0.049) at the same level. Greater asymmetry in MF+SCer CSA was also associated with greater MCC (p=0.006). Similarly, greater asymmetry in FCSA and FCSA/CSA of the entire extensor muscle group was associated with greater MCC (p=0.011, p=0.013). There was no significant association between muscle measurements obtained at the level below the level of maximum compression, MCC and MSCC. CONCLUSIONS: Greater MCC is associated with increased fatty infiltration and greater asymmetry of the deep extensor cervical muscles in patients with DCM. Our findings also suggest that MCC is a better indicator of cervical muscle morphological changes than MSCC. Whether such markers of muscle degeneration can be modified with pre- or post-operation rehabilitation exercise to impact patient health related quality-of-life scores and neck function warrant further investigations. Given the importance that patients with DCM place on neck pain, this work has important translational significance.

Poster Session 1

Thursday June 23, 2022

A - Aging

P1-A-1 The impact of equine-assisted therapy on the stomatognathic system and self-perceived oral health in older adults

Edneia de Mello[1], Lígia Maria Gonçalves[1], Paulo de Vasconcelos[1], Christiane Martins[2], Elaine Cristina Soares[2], Octávio Barbosa Neto[3], Edmar Mendes[3], Simone Cecílio Regalo[1], Selma Siessere[1]
[1]Ribeirão Preto School of Dentistry of University of São Paulo, [2]Vassoural Hippotherapy Association, [3]Federal University of Triângulo Mineiro

BACKGROUND AND AIM: The adequate and harmonic functioning of the stomatognathic system reflects on the performance of its functions (chewing, swallowing, sucking, breathing, speech articulation), on the postural balance and on the quality of life of human being. Equine-Assisted Therapy is a complementary treatment modality that is effective in promoting biopsychosocial gains and improving the quality of life of individuals of different age groups, including older adults. Human-equine contact is capable of influencing several systems simultaneously, such as somatosensory, vestibular, musculoskeletal and cognitive. However, the impact that this integrative therapy has on the stomatognathic system is still a knowledge gap. Therefore, the present study aimed to investigate the effect of Equine-Assisted Therapy on the performance of the stomatognathic system and on the self-perception of oral health in older adults. METHODS: The project was approved by the Ethics Committee of the Ribeirão Preto School of Dentistry of University of São Paulo, in accordance with Resolution 466/12 of the Brazilian National Health Council (CAEE: 98201118.2.0000.5419) and by the Brazilian Registry of Clinical Trials (ReBEC), accessed through the link (http://www.ensaiosclinicos.gov.br/rg/RBR-6phs67/). Sixteen individuals participated in the study, with a mean age of 69 ± 5.6 years. The Equine-Assisted Therapy Program consisted of two weekly interventions, non-consecutive days, lasting from 30 to 45 minutes, for 12 weeks, preceded by a week of familiarization. Before and after the Equine-Assisted Therapy Program, the Delsys Trigno TM wireless electromyograph was used, with surface electrodes placed on the masticatory muscles: masseter and temporal, bilaterally; the Iowa Oral Pressure Instrument to measure lip, tongue, and cheek pressure; the Kratos digital gnatodynamometer to measure maximal molar bite force and the Geriatric Oral Health Assessment Index (GOHAI) questionnaire to measure the self-perceived oral health of older adults. Data were tabulated and submitted to statistical analysis ($p \leq 0.05$). RESULTS: After the Equine-Assisted Therapy program, there was a significant reduction in the electromyographic activity for the muscles evaluated ($p \leq 0.05$), clinical increase in the mean values of the maximum pressure of the lips, tongue and cheeks, with a statistical difference for the tongue ($p = 0.0087$), clinical increase in the mean values of maximum right and left molar bite force and change in the GOHAI classification from "fair" to "optimal". CONCLUSIONS: The Equine Assisted Therapy Program promoted improvements in the performance of the stomatognathic system and in the self-perception of oral health in older adults. It is known that oral health reflects on the overall health of the body. On the other hand, the gains promoted by complementary therapies reflect on the general health, including its integral and inseparable oral health.

P1-A-2 Hand-eye Coordination performance according to physical activity level in older individuals

Saleh Hammad[1], Layale Youssef[2], Rami Hammad[3], Ibrahim Dabayebeh[4], Philippe Noirez[5], Haidar Djemai[6]

[1]Al-Ahliyya Amman University, [2]Université de Montréal, [3]UQAM, [4]University of Jordan, [5]University of Reims, [6]Université de Paris

BACKGROUND: Coordination is an essential ability for targeted movements. It is well-known that the coordination decreases with age since older adults have a slower reaction time. Physical activity has a positive effect on physiological changes resulting from ageing. Thus, the aim of the present study is to see whether the physical activity level influences the hand-eye coordination performance in old individuals. METHODS: A total of 36 participants including 14 active young individuals (20.28 ± 3.95 yrs), 14 old active individuals (63.00 ± 6.57 yrs) as well as 8 inactive old individuals (64.75 ± 3.41 yrs) performed a hand-eye coordination test (HEC) (Lafayette). The HEC test consists on holding a stylus for 5 s in the middle of 9 different holes becoming progressively smaller (from 1.156 inch / 1st hole to 0.0625 inch / 9th hole), and by trying to avoid touches of the hole limits. A two-way repeated measures ANOVA was used for the statistical analysis and significance level was set at $p<0.05$. RESULTS: When evaluating the activity level effect in old individuals, significant differences were observed in 3 holes (0.093, 0.078 and 0.093) where the number of touches were significantly higher ($p < 0.05$) for old inactive individuals. CONCLUSIONS: The hand-eye coordination performance is decreased with age and attenuated with physical inactivity (significant differences between active and inactive old individuals). Being aged and inactive has a double impact on the coordination performance. Keywords: Hand-eye Coordination, Physical activity level, Aging

P1-A-3 The effects of slow breathing on postural muscles during unexpected standing perturbations in older adults

Patrick Siedlecki[1], Tanya Ivanova[1], Jayne Garland[1]
[1]*Western University*

BACKGROUND AND AIM: During periods of postural instability, a fall can be prevented with quick adjustments to muscle torques that allow for the rapid stabilization of the center of mass within the base of support. Failure to maintain balance can have devastating effects. Age-related deterioration of sensorimotor function can lead to diminished balance performance in those over 65 years of age. The acute psychological and physiological effects of slow breathing have been documented previously and include decreased anxiety, increased pain sensitivity threshold, and lowered heart rate and blood pressure. Recent findings suggest an interaction between volitional slow breathing and improved postural control during quiet standing (Rodrigues et al., 2018) and transitions between postures (Barbosa et al., 2017); however, the effects of slow breathing during unexpected threats to standing balance have not been studied. Therefore, the purpose of this study was to examine the effect of slow breathing on the latency and amplitude of postural muscle responses to perturbations of the base of support in healthy older adults. METHODS: Twenty participants, aged between 60 and 86 years, completed two balance perturbation tests while standing on a treadmill. These included sets of perturbations that required feet-in place strategies to recovery balance while spontaneously breathing and while breathing at 6 breaths per minute. Each perturbation set consisted of 25 posteriorly-directed accelerations of the treadmill belts every 8-12 seconds. Muscle burst latency and amplitude were measured using surface electromyography from the right limb for the rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), medial hamstring (MH), tibialis anterior (TA), soleus (SOL), and lateral (LG) and medial (MG) gastrocnemius, while a respiratory belt was used to measure respiratory rate. RESULTS: Results indicated that muscle latency decreased in the MH ($p=0.001$), SOL ($p<0.001$), LG ($p<0.001$), MG ($p=0.004$), and TA ($p=0.001$), but not in the quadriceps (RF, VL, VM; $0.19 < P > 0.826$)

muscles during the slow breathing test compared to spontaneous breathing. Muscle burst amplitude 200 ms after the onset of perturbation was reduced in the SOL ($p=0.025$) muscle only, but was not significantly different in the remaining muscles ($0.162 < p > 0.991$) during the slow breathing test compared to spontaneous breathing. CONCLUSIONS: Thus, reducing respiratory rate to approximately 6 breaths per minute may have benefits to dynamic postural stability and responses to unexpected perturbations in older adults. The findings may be attributed to volitional breathing modulating motoneuron excitability, although further investigation is warranted.

P1-A-4 Impact of prolonged bed rest on lower limb strength and electromyographic activity

Philippe St-Martin[1], Jean-Christophe Lagacé[1], Mathil Ruel[1], Guillaume Léonard[2], Karen Lambert-Cordillac[3], Eléonor Riesco[1], Jamie McPhee[4], Isabelle Dionne[1]
[1]Université de Sherbrooke, Faculty of Physical Activity Sciences / Research center on aging, [2]Université de Sherbrooke, Faculty of Medicine and Health Sciences, / Research center on aging, [3]PhyMedEx, Université de Montpellier, INSERM, CNRS, [4]Manchester Metropolitan University

Introduction: Immobilization and prolonged bed rest during a hospital stay can lead to considerable loss of muscle strength, particularly in the lower limbs. These losses of physical capacity can be a turning point in the autonomy of an older person and accelerate the aging process. Muscle atrophy is the most referred mechanism that may contribute to strength loss in the context of immobilization. However, the weakening precedes and exceeds the rate of atrophy, suggesting that other mechanisms are involved. A mechanism that could potentially explain this latency between atrophy and weakening would be the deterioration of the neuromotor junction. However, the current literature does not allow us to understand the mechanisms involved in the deterioration of the neuromotor junction and weakening following prolonged bed rest. Head-down bed rest (HDBR) is an accelerated aging analog model used to understand the aging of the musculoskeletal system. Objectives: The first objective of the project is to verify how 2 weeks of head-down bed rest influence the strength and neuromotor activity of the lower limbs. As these deteriorations are generally secondary to muscle disuse, the second objective of the study is to verify if exercise can prevent the deterioration of strength and neuromotor activity. Methods: Maximal voluntary contraction strength (MVC) of the quadriceps will be measured in 24 participants (aged 55-65; 12 men and 12 women) with isometric knee extension on a dynamometer (Biodex, System 3). Participants will then perform a contraction at 25% of MVC during which surface and intramuscular EMG signals will be recorded. In addition, the amplitude and area of the compound muscle action potential will be determined by stimulating the femoral nerve. These different tests will allow us to estimate the number of motor units, their size, and the stability of the neuromotor junction. The participants will then be exposed to an analog of accelerated aging for 14 days. Briefly, participants will be continuously bedridden at 6 degrees HDBR for 2 weeks and all the tests will be repeated following the immobilization period. Half of the participants will be engaged in muscular and cardiovascular exercises for up to an hour of daily physical activity, while the other half will be subjected to passive mobilization by a physical therapist during immobilization. Results: Data collection is ongoing but preliminary results suggest that HDBR impairs strength and neuromotor activity and that regular exercise mitigates the deleterious effects of HDBR in terms of strength and neuromotor activity. The complete results will be presented at ISEK 2022.

P1-A-5 iPhone accelerometry provides a sensitive in-home assessment of age-related changes in standing balance

Elizabeth Coker[1], Anat Lubetzky[2]
[1]NYU/Tisch School of the Arts, [2]NYU/Steinhardt School of Culture, Education and Human Development

BACKGROUND AND AIM: Impaired balance increases risk of falling in aging individuals. Restrictions due to the COVID-19 pandemic underscore the importance of developing tools that can measure balance changes in aging individuals remotely. The purpose of this study was to evaluate a fully remote balance assessment using a custom iPhone application as the necessary first step towards developing scalable, stable, and sensitive in-home balance testing. Our first aim was to determine the stability of iPhone accelerometer-derived data via sampling framerate and drift within testing sessions. Our second aim was to determine the sensitivity of our application to age, visual condition, and stance. METHODS: Twenty healthy adults, 10 younger (24.8 +/- 2.8 years) and 10 older (67.4 +/- 5.9 years), were monitored via videoconference while standing with feet together (FT), in tandem stance (TAN), and on single leg (SL), holding an iPhone flush against the chest. Half of these trials were performed with eyes open (EO) and half with eyes closed (EC). Their balance was quantified using iPhone accelerometer-derived data, processed offline for mediolateral (ML) root mean square acceleration (RMSA). RESULTS: We found that sampling framerate and data drift were stable between iPhone models and software versions. We observed significant main effects of stance (increased RMSA with smaller base of support), age (increased RMSA in older individuals) and vision (increased RMSA with eyes closed). Significant interactions were observed such that older individuals showed greater increases in RMSA compared to younger individuals in TAN and SL stances, and both groups showed greater increases in RMSA with eyes closed during TAN and SL stances compared to FT. CONCLUSIONS: iPhone accelerometry appears stable between devices and operating system versions, suggesting that acceleration outcomes arising from different devices may be compared as long as protocol are standardized. In this small sample, iPhone-derived acceleration measures were sensitive to age during tandem and single leg standing. Younger and older adults did not differ in ability to stand with feet together under either visual condition, suggesting this stance demonstrates a floor effect within the studied population. Likewise, during tandem stance, no differences between age groups were revealed when standing with eyes open. However, when standing in a tandem with eyes closed, individuals in the older group showed significantly more variable trunk accelerations compared to younger adults. Older individuals also performed significantly worse compared to younger individuals during single leg stance with eyes open and eyes closed. Our results underscore the importance of choosing tasks that discriminate well between age groups, which are neither too simple (e.g., feet together) nor potentially risky to perform in the home (e.g., single leg/eyes closed), and support the validity of this protocol for broader investigation.

B – AI, Data Fusion, and Machine Learning

P1-B-6 Preseason elite female soccer subgroups recognition based on multiple injury risk biomechanical markers is improved using non-linear instead of linear dimension reduction: A short communication

Carlos De la Fuente[1], Rony Silvestre[1], Macarena Soldan[1]
[1]MEDS Clinic

BACKGROUND AND AIM: Multiple biomechanics injury markers in soccer are often collected to plan the preseason. However, a high-dimensional dataset can cause the course of dimensionality (when the dimensionality increases, the volume of the space increases so fast that the available data become sparse), which difficult both the recognition of risk of injury and the individualized training prescription

based on deficiencies. Hence, we briefly report the influence of non-supervised dimensionality reduction for clustering improvements propose on multiple biomechanics injury markers in an elite female soccer team. METHODS: We introduce the use of dimensionality reduction of the linear principal component (pca), non-linear kernel principal component (k-pca), t-distributed stochastic neighbor embedding (t-sne), and uniform manifold approximation and projection (umap) for the female elite soccer team of Colo-Colo. Multiple biomechanics injury markers were obtained from strength testing, stiffness testing, vertical jump testing, stabilization exercise tolerance, Drop test, dynamic postural index, lading error score system, and running assessment. RESULTS: Umap facilitated the recognition of three clusters where one cluster had a profile of better muscle condition. In contrast, the other clusters had a profile coherent with dynamic valgus and muscle function impartment. Only umap was able to identify well-defined dense clusters while pca, k-pca, and t-sne failed. For our dataset, umap allows the extraction of the latent patterns of injury markers. CONCLUSIONS: Appropriate recognition of team subgroups supports better exercising prescription for preseason based on functional deficits for vulnerable players who can suffer musculoskeletal injuries.

C - Biomechanics

P1-C-7 ELECTROMYOGRAPHIC FOLLOW-UP OF THE CONSEQUENCES OF BUCCAL FAT PAD REMOVAL IN THE MASSETER AND TEMPORALIS MUSCLES

Alice Helena de Lima Santos Cardoso[1], Thamyres Branco[1], Nicole Barbosa Bettiol[1], Isabela Hallak Regalo[1], Paulo Batista Vasconcelos[1], Marcelo Palinkas[1], Selma Siéssere[1], Simone Cecílio Hallak Regalo[1]
[1]São Paulo University

BACKGROUND AND AIM: Buccal fat pad (BFP) removal is an aesthetic procedure that is increasingly in demand and the consequences of its removal are still little discussed in literature. This study aimed to carry out a electromyographic follow-up of the consequences of buccal fat pad removal in the masseter and temporalis muscles of ten women. METHODS: Ten women underwent electromyography, performing tasks of laterality, protrusion, maximal voluntary contraction and rest, in three stages: before, 30 days and 60 days after the surgery. Assessments were performed on the masseter and temporalis muscles on both sides, using a wireless system (Trigno, Delsys Inc., Boston, MA, USA). Data were tabulated and submitted to statistical analysis using the repeated-measure test ($p < 0.05$). This study was submitted and approved by the Research Ethics Committee (process # 10589419.0.0000.5419). RESULTS: Significant differences were observed for the right temporalis muscle at rest between the 3 periods ($p=0.003$). It was observed that after 30 days of BFP removal there was a decrease in electromyographic activity in almost 100% of the muscles evaluated for mandibular tasks. After 60 days, an increase in electromyographic activity was observed in almost all muscles, reaching values close to the values before BFP removal. CONCLUSION: This study suggests that there is a functional recovery of the masticatory muscles after 60 days of BFP removal.

P1-C-8 Concurrent validity and test-retest reliability of a wearable inertial sensor to measure the active range of motion on healthy subjects

Corrado Cescon[1], Simone Ballerini[1], Nicolò Castellini[2], Anna Folli[1], Giulia Masoni[1], Giulia Mazzi[1], Andrea Tettamanti[2], Marco Barbero[1]
[1]University of Applied Sciences and Arts of Southern Switzerland, [2]I.R.C.C.S. Ospedale San Raffaele

BACKGROUND AND AIM; In rehabilitation, the assessment of the subject range of motion is a crucial aspect, which allows to plan therapeutic interventions. Precise and easy to use tools thus allow to

improve the quality of the measurements and to minimize the time for assessment procedures. The aim of this study is to evaluate the validity and reliability of an inertial sensor for measuring active joint range of motion. METHODS; The experimental design of the study is test-retest reliability and concurrent validity. The study was conducted on 39 healthy subjects. The sample size was determined according to Walter et al. (1998). The joint range of motion was determined with two systems: an IMU (RoMot, OT-Bioelettronica) and an optoelectronic motion capture system (Optitrack). Participants were asked to perform six movements repeated three times each. The movements required were: shoulder flexion, shoulder abduction, cervical rotation, shoulder external rotation, knee flexion and ankle plantar- and dorsiflexion. All the six movements were used for test-retest reliability. While only the first three were considered for concurrent validity. RESULTS; The intraclass correlation coefficient (ICC) values of concurrent validity, with a confidence interval (CI) of 95%, were between 0.93 and 0.99, with highest values for cervical rotation. For the test-retest reliability, the ICC values were between 0.89 and 0.98 with lower values for ankle dorsiflexion. The data obtained on concurrent validity and test-retest reliability expressed very good reliability and excellent reliability, based on the evaluation criteria of Koo & Li (2016). The figure shows the correlation and ICC for each individual movement. The lowest reliability was observed in the ankle dorsiflexion (right bottom panel) CONCLUSIONS; The investigated inertial sensor revealed to be a valid and reliable instrument for the assessment of ROM on all the planes of movement and for the analyzed joints, in particular the cervical rotation, the shoulder external rotation and the knee flexion.

P1-C-9 Evaluation of knee Helical Axis dispersion during walking after isometric muscle training

Corrado Cescon[1], Paola Adamo[2], Francesco Oddenino[2], Federico Temporiti[2], Roberto Gatti[2], Marco Barbero[1]
[1]University of Applied Sciences and Arts of Southern Switzerland, [2]Humanitas University

BACKGROUND AND AIM; Different types of muscular training create different metabolic stress and muscular adaptations. Strength training could modify displacement of knee center of rotation (CoR) during movement, which can be estimated through Helical Axes (HAs) dispersion. The primary aim of the study was to describe knee HAs dispersion during walking after two different strength training in healthy subjects. The secondary objective was to assess the physiological variability of knee HAs dispersion. METHODS; Thirty young subjects (22.6±2.1 years) were randomized in two groups: MT group performed quadriceps and hamstrings isometric contractions at 90% of the MVC, RT group at 30%. All participants were asked to walk on a treadmill at spontaneous speed during two different recording sessions, seven days apart (T0-T1pre). After the second evaluation (T1pre), they underwent the first training and they were re-assessed immediately after that (T1post). Subsequently, they underwent 2 weeks of training and, in the last session, they performed the last evaluation, before and after the last training (T2pre-T2post). The gait phases were identified using the position of markers placed on both heels and toes. Helical axis were computed for each knee joint during 100 steps on the treadmill. Knee HAs dispersion was quantified using mean distance (MD) and mean angle (MA). RESULTS; No differences between group over time were found for MD and MA in dominant and non-dominant side ($p>0.05$). Inter-session reliability was good/excellent for both MD and MA in sagittal plane (ICC ≥ 0.74 except one ICC= 0.70). The figure below represents an example of Helical Axes dispersion during 100 gait cycles. Different colours represent different stride phases. CONCLUSIONS; Resistance and maximal strength training do not modify knee HAs dispersion during walking in young, healthy subjects. MD and MA are

reliable HAs dispersion parameters which can be used to quantify knee CoR displacement during lower limb movements.

P1-C-11 The effect of the peculiar shape of Japanese wooden clogs (geta) on gait

Kazuya Matsushita[1], Hiroki Saito[2], Sakiko Ohnishi[2], Takashi Nakayama[2]
[1]Aobadai-TAKEDA Orthopedic, [2]Tokyo University of Technlogy

Background and Aim Geta, often referred to as Japanese wooden clogs, are a type of footwear traditionally favored by the Japanese and are extremely unique in their shape and can be said to be a uniquely Japanese type of footwear that has no parallel in the world. Geta are basically a wooden board called a 'tooth' that stands vertically to the ground with a wooden board placed horizontally over it that usually has a geta strap attached. Typical geta have two-teeth but there are also single tooth geta. Although geta are rarely used in modern daily life, they are a familiar footwear for Japanese people, who often wear them when dressing in kimono (traditional Japanese clothing). There are very few examples of kinematic studies using single-toothed geta, and there is little kinematic knowledge about how geta affect humans and whether they are useful in physical exercise. Methods Nine healthy males participated in this study. Their mean (standard deviation) age, height, and weight were 23.2 (2.3) years, 166.4 (7.2) cm, and 58.2 (6.6) kg, respectively. Prior to measurements, the purpose and procedure of this study were explained in detail, and informed written consent was obtained from all subjects. The subjects went barefoot and wore two different pairs of geta. Before the measurements were taken, subjects were allowed to practice walking with each pair of geta to achieve a comfortable gait. A VICON system was used to capture three-dimensional movements. VICON data were recorded while subjects walked, from the time of heel contact to the completion of the walking cycle. Data were recorded throughout the right stance phase of the walking cycle. We defined the stance phase of the walking cycle, before and after the partial pressure of foot floor reaction, as the 'braking phase'. The latter phase was defined as the 'acceleration phase'. Statistical analyses were conducted using one-factor ANOVA and the Tukey-Kramer correction test. Results There were significant differences in the peak values of the floor reaction forces for vertical forces. The vertical component was significantly higher for barefoot and two-tooth geta than for single-tooth geta. In terms of the peak values of joint moments, the plantar flexion moment of the ankle joint increased significantly more in the single-tooth geta than in barefoot and two-tooth geta. Similarly, the dorsiflexion moment increased significantly more in barefoot and two-tooth geta than in the one-tooth geta (Fig.1). Discussion and Conclusion When wearing single-tooth geta, the heel rocker function advocated by Jacquelin Perry could not be performed due to the shape of the footwear, so the impact was absorbed by the plantar dorsiflexion movement of the ankle joint and the exertion of the plantar flexion moment while shortening the braking period. Based on these findings, single-tooth geta are considered to be relatively high-load footwear because they require a flexible joint strategy of the ankle joint.

P1-C-12 Ankle joint stiffness during quiet standing is greater in individuals with incomplete spinal cord injury

Jonguk Lee[1], Kaylie Lau[1], Kai-Lon Fok[1], Jae Woung Lee[1], Katherine Chan[2], Janelle Unger[3], Kristin Musselman[1], Kei Masani[1]
[1]University of Toronto, [2]Toronto Rehabilitation Institute, [3]Western University

BACKGROUND AND AIM: Individuals with incomplete spinal cord injury (iSCI) often show compromised balance control in the upright posture, resulting in increased fall risk. Since the ankle joint is the first major joint connecting the body to the external environment, deteriorated control of this joint may be the critical factor of postural instability in individuals with iSCI. We recently showed that individuals with iSCI experience an increased prevalence of co-contractions in the ankle musculature which may be a contributing factor in their larger postural sway velocity compared to the able-bodied (AB) individuals. Since muscle co-contraction leads to higher joint stiffness, we hypothesized that individuals with iSCI manifest increased stiffness in their ankle joints. Therefore, the primary purpose of this study was to evaluate the ankle stiffness in individuals with iSCI to elucidate the cause of their instability during upright standing. The secondary purpose of this project was to analyze the unit sways of individuals with iSCI to further gain an understanding of the difference in postural sway. METHODS: A total of 15 individuals with iSCI and 14 age- and sex-matched AB participants performed quiet standing under eyes open (EO) and eyes closed (EC) conditions. The kinetic and kinematic data were recorded using a force platform and a motion capture system, respectively. We used two distinct methods to evaluate the ankle stiffness as a secondary effort to compare the association between them. For the first method, proposed by Winter et al., the ankle stiffness was calculated by approximating quiet standing as an inverted pendulum with a mass-spring-damper model. For the second method, based on the work by Loram and Lakie, we decomposed postural sway into unit sways and measured the slope of the torque-angle curve. The former method can be understood as finding the stiffness that matches the overall postural movement of the participant during quiet standing, while the latter is a direct measurement of the stiffness based on the measured ankle torque and angular displacement. RESULTS: Using the former method, we found the ankle stiffness to be significantly greater in the individuals with iSCI than in the AB participants (EO: 1426.2 Nm/rad vs 903.03 Nm/rad; EC: 1532.2 Nm/rad vs 1058.4 Nm/rad, $p = 0.023$). The latter method did not lead to a statistically significant difference between the two groups, while there was a tendency for stiffness to be greater in the iSCI group (EO: 1273.9 Nm/rad vs 851.75 Nm/rad; EC: 1340.9 Nm/rad VS 976.23 Nm/rad, $p = 0.051$). Both maximal speed ($p < 0.001$) and magnitude ($p = 0.002$) of the unit sways were significantly larger in the iSCI group, while there was no difference in the sway duration ($p = 0.55$). CONCLUSIONS: These results suggest that increased ankle stiffness may be a factor contributing to both instability in the upright standing and the changes in postural sway among individuals with iSCI.

P1-C-13 The medial longitudinal arch height is determined primarily by the stiffness of the plantar aponeurosis

Momoka Nakamura[1], Jota Suzuki[1], Moeka Samoto[1], Yasuhide Yoshitake[1]
[1]Shinshu University

AIM: The human foot is a flexible structure, enabling absorption of the impact force when the foot contacts the ground, support of the weight during foot flat phase, and transportation of the center of gravity into propulsive force. Passive elastic recoil of the plantar aponeurosis (fascia) contributes to positive work generation for propulsion at the stance phase, so-called the windlass mechanism, which stiffens the long arch during toe extension. Despite some evidence by use of the cadaver suggesting that increase in stiffness of the plantar aponeurosis at the contact phase would contribute to following release of elastic energy, mechanical properties of the plantar aponeurosis and it's association to the deformation of the foot have not yet fully elucidated in living humans. Accordingly, the purpose of this study was to examine the relationship between mechanical loading of the foot and mechanical properties of the plantar aponeurosis, and deformation of the foot in living humans. METHODS: Ten healthy young adults sat with their knee flexed and the center of their right foot long arch placed at the center of the ~9 cm distance between two force plates that measured applied forces. The shank was positioned at approximately 10° of flexion relative to vertical, similar to the position during quiet standing, with the femur positioned parallel to the force plate. Loads were applied to the distal aspect of the thigh via a custom-built rig. Applied load was increased from 10% body mass (BM) to 50% BM with increments of 10% BM. Shear wave velocity (SWV) of the plantar aponeurosis was measured with ultrasound shear wave elastography to evaluate the mechanical properties. The probe was fixed between force plates in the longitudinal direction at the center of the plantar fascia with gentle compression. As an index of deformity of the foot, the height of the medial longitudinal arch (MLA) was assessed by measuring the length between navicular tuberosity and the bottom face of the sole foot using ultrasound B-mode images. Surface EMG were measured from the abductor hallucis and flexor hallucis longus of the right foot to confirm the absence of muscle activity. RESULTS: SWV increased with increasing load applied to the distal aspect of the thigh ($P < 0.05$) as shown by values of 4.59 ± 1.01 m / s for 10% BM and 8.11 ± 0.58 m / s for 50% BM. Height of MLA decreased with increasing load ($P < 0.05$) as shown by values of 4.27 ± 0.48 cm for 10% BM and 3.81 ± 0.55 cm for 50% BM. When the rate of changes in these values between 10% and 50% BM were compared, there was a negative correlation between SWV and MLA ($r = 0.91$, $P < 0.05$).CONCLUSION: These results suggest that mechanical loading of the foot is accompanied both with increases in stiffness of the plantar aponeurosis and decrease in MLA height and that the foot deformation may be determined primarily by the stiffness of the plantar aponeurosis.

E – Clinical Neurophysiology

P1-E-15 Estradiol increases cortical inhibition in primary motor cortex

Subaryani Soedirdjo[1], Luis Rodriguez II[1], Hyuangtaek Kim[1], Conner Hutcherson[1], Bailyn Piecewicz[1], Kathleen McGovern[1], Caitlin Kumala[1], Navoda Perikala[1], Lynn Rogers[2], Yasin Dhaher[1]
[1]University of Texas Southwestern Medical Center, [2]Northwestern University

BACKGROUND AND AIM: Animal models show that estradiol (E2) receptors are present in the central nervous system, including the cortex (Kritzer, 2002). In humans, direct evidence is lacking, but hormone concentrations have been linked to brain conditions like seizure, cognitive function and emotional states (Toffoletto, Lanzenberger, Gingnell, Sundström-Poromaa, & Comasco, 2014; Velí?ková & DeSantis, 2013). The link between E2 and the motor function of the brain is unclear. Our earlier examination indicated that the aggregate motor excitability can be influenced by hormonal fluctuations in young healthy women (Rogers & Dhaher, 2017). Indeed, our data indicated that E2 plays an "amplifying" agent of repetitive transcranial magnetic stimulation (rTMS) mediated cortical inhibition. It is not clear if this effect was colored by the combined inhibitory state of the rTMS stimulus used in that paradigm. Thus, we aim to unfold this aggregate effect by interrogating the isolated role of E2 on one of the constituencies of inhibition in motor cortex, the inhibitory intra-cortical interneuron circuits. We hypothesize that the intra-cortical inhibition will change with different E2 levels. METHODS: Thirteen young females with normal menstrual cycle were tested at menses and peak E2, confirmed by the serum E2 level. A TMS paired-pulse paradigm was used to test the excitability of inhibitory intra-cortical interneurons of the tibialis anterior muscle while participants generated 10% of maximal ankle torque (active condition). The conditioning stimulus (CS) intensity was 90% of the active motor evoked potential (MEP) threshold, defined as the minimal intensity eliciting MEPs distinguishable above background muscle activity. The test stimulus (TS) intensity was the minimal intensity producing peak-to-peak MEP amplitudes of 0.5-1.5 mV. The inter-stimulus intervals (ISI) included 2, 3, 4, 5, and 6 ms. The degree of inhibition produced by the CS on the TS at each ISI was calculated as the ratio of the conditioned MEP to the average unconditioned MEP amplitude. Repeated measures ANOVA was used to compare the normalized MEP amplitude across ISIs between two E2 levels. RESULTS: No significant E2 level effect (p=0.22) or ISI effect (p=0.18) was observed. The E2 level by ISI interaction showed a trend towards significance (p=0.07). Post-hoc pairwise comparisons using one-sided paired t test indicated that the normalized conditioned MEP amplitudes measured at 2-ms (0.76 ± 0.25 vs 0.91 ± 0.25; p<0.05, n=13) and 6-ms ISI (0.80 ± 0.16 vs 1.05 ± 0.23; p=0.01, n=9) was significantly smaller at peak E2 than at menses. CONCLUSIONS: The preliminary result supports our hypothesis that the GABAAR-mediated intra-cortical inhibition is enhanced by high estradiol level, potentially via a genomic pathway resulting in increased GABAAR mRNA expression (Herbison & Fenelon, 1995). Estradiol may influence neuromuscular control via modulating intra-cortical inhibition.

P1-E-16 Analysis of electromyographic activity of respiratory muscles and accessories of individuals with stroke.

Camila Gonçalves[1], Isabela Regalo[1], Gabriel Silva[1], Guilherme Gallo Gomes[1], Edson Verri[1], Robson Felipe Lopes[1], Selma Siéssere[1], Simone Cecilio Regalo[1]
[1]FORP USP

BACKGROUND AND AIM: Evaluate and compare the electromyographic activity of respiratory and accessory muscles of individuals with a clinical diagnosis of ischemic and hemorrhagic stroke compared to individuals without neurological impairment (control group).METHODS: Twenty-four individuals aged between 30 and 80 years participated in this study, divided into two groups: 12 subjects from the stroke group (GAVC) and 12 individuals without neurological impairment from the control group (CG). The research subjects were submitted to surface electromyography examination of the following muscles: right sternocleidomastoid, right pectoralis major, right external intercostal, right diaphragm, right anterior serratus, right external oblique and rectum abdominal. Under the following clinical conditions: respiratory rest; maximum inspiration of the residual volume and maximum expiration of the total lung capacity and respiratory cycle. The data were statistically analyzed by the SPSS program comparing independent samples (Test t), adopting a significance level of 95% (p≤0.05), in addition to descriptive analysis (mean and standard error). RESULTS: The results of this research showed statistically significant values with lower means of electromyographic activity in the clinical condition of respiratory rest for the pectoralis major and external oblique muscles. In the clinical condition of maximum inspiration, the lowest averages were anterior serratus, rectum and external oblique muscles. In the clinical condition of maximum expiration, no changes were observed in the electromyographic activity of the evaluated muscles. For the clinical condition of respiratory cycle, the lowest mean sums were for the pectoralis major, anterior serratus, rectum abdominal and external oblique muscles. CONCLUSION: It can be concluded that individuals with stroke had neuromuscular problems, with significant changes in the electromyographic activity of respiratory and accessory muscles.

F – Electrical Myostimulation

P1-F-17 Paired associative stimulation on the soleus H-reflex using motor point and peripheral nerve stimulation

Kai Lon Fok[1], Naotsugu Kaneko[2], Shirin Tajali[3], Kei Masani[1]
[1]University of Toronto, [2]University of Tokyo, [3]KITE

In young healthy individuals, the soleus (SOL) H-reflex is inhibited during standing to provide better control and postural stability. However, in individuals with decreased neurological function this H-reflex modulation is shown to be impaired, specifically it may be overly excited. In some instances, the excessive Ia-α motoneuron synapse results in spasticity of the muscles. Thus, a method to inhibit the H-reflex may lead to reduced spasticity and improved standing performance in individuals with decreased neurological function. Recently, paired associative stimulation (PAS) has been shown to strengthen residual motor pathways via spike timing dependent plasticity (STDP) in the corticospinal tract, but few studies have looked at modulating the spinal reflex pathways and even fewer aiming to inhibit this pathway. Peripheral nerve stimulation can be used to send a signal up the Ia-sensory nerve. Also, motor point stimulation (MPS), which electrically stimulates the motor portion of the muscle that is the most sensitive to electrical stimulation, sends a signal up the α motoneuron cell body antidromically. Thus, PNS and MPS can be used to generate signals that both arrive at the Ia-α motoneuron synapse. If the spinal reflexes can be modulated by STDP, and a combination of MPS and PNS is timed appropriately, then the H-reflex amplitude will decrease, but no change in H-reflex amplitude is expected when applying MPS or PNS only. To test this hypothesis, six young healthy participants (5M/1F: 26.8 ± 4.1 yrs) received one of the three following conditions on days separated by at least 24 hours: 1) Inhibition of H-reflex PAS, 2) MPS only or 3) PNS only. The latency of the H-wave induced by PNS, and the latency of the F-wave induced by MPS were measured to ensure the antidromic signal from MPS arrived 5ms prior to the orthodromic signal from PNS at the Ia-α motoneuron synapse to inhibit the H-reflex amplitude. MPS was delivered at 120% of the intensity needed to produce a maximal M-wave, and PNS was delivered at an intensity to produce a maximal H-wave. For each condition, 200 stimuli were given at a frequency of 0.1Hz. The H- and M-wave recruitment curves of the SOL were measured immediately prior to, immediately after, 30 minutes and 60 minutes after the intervention. At each time assessment, the H-wave was normalized to the corresponding max M-wave amplitude. These normalized H-wave amplitudes were then compared across condition and times using a two-way ANOVA (3 conditions × 4 times). No main effects of condition ($F = 3.035$, $p = 0.093$) or time ($F = 2.437$, $p = 0.105$) were found. Additionally, no interaction between condition and time was found ($F = 0.218$, $p = 0.986$). These results suggest that relying solely on STDP may be insufficient to inhibit the SOL H-reflex. The influence of other pathways as well such as of pre- or post-synaptic projections onto the Ia-α motoneuron synapse on this unexpected result was discussed.

P1-F-18 Conduction velocity during electrically stimulation contraction at various joint angles and during joint movements with different angular velocities

Tetsuya Hirono[1], Kohei Watanabe[1]
[1]Laboratory of Neuromuscular Biomechanics, School of Health and Sport Sciences, Chukyo University

BACKGROUND AND AIM: Muscle fiber conduction velocity (CV) recorded from multi-channel surface electromyography (EMG) is used for an evaluation tool of neuromuscular fatigue. The method can be useful for an application that assesses peripheral muscular fatigue selectively. However, muscle fiber geometry is altered at different joint angles and during shortening or lengthening of whole muscle; therefore, CV can be affected by joint angle and joint movement. The purpose of this study to investigate CV during electrically evoked contraction at different joint angles and during joint movements with different angular velocities. METHODS: Eleven healthy young men participated in this study. They seated in a dynamometer and were fixed knee joint at 90˚. After searching the neuromuscular junction of vastus lateralis muscle on the line from lateral edge of patella to greater trochanter, the stimulation electrode was attached there, and linear electrode array was attached on the proximal line to record EMG signals. The intensity of the stimulation was determined based on clearly propagated muscle fiber action potentials during electrical stimulations. In static conditions with resting, EMG signals during electrical stimulation were recorded while their knee joint was fixed at 75, 90, 105, 120, 135, 150, 165 and 180˚ (full extension = 180˚). In dynamic conditions with resting, EMG signals during electrical stimulation were recorded around 135˚ while their knee joint was moved by the dynamometer with angular velocities of 30, 90 and 180˚/s in both directions. CV were calculated using an algorism in OTBioLab software with a 1-s time window. To confirm the accuracy of CV calculation, the correlation coefficient was also calculated. Repeated analyses of variances (ANOVAs) were conducted for compare CVs among different joint angles and joint movements. RESULTS: In static condition, one-way ANOVAs for both CV and correlation coefficient revealed no significant differences among various joint angles ($p > 0.05$). In dynamic condition, two-way ANOVA (velocity × direction) for CV revealed a main effect of direction ($p < 0.05$), and two-way ANOVA for correlation coefficient revealed main effects of both velocity and direction ($p < 0.05$). During shortening, CV was significantly faster and correlation coefficient was significantly higher value ($p < 0.05$). The correlation coefficient during the movement of 30˚/s was significantly greater than that during the movement of 180˚/s ($p < 0.05$). CONCLUSIONS: In static condition, CV during electrically stimulation contraction and the accuracy were not different among various joint angles. In dynamic condition, CV during shortening was faster than during lengthening. In addition, the accuracy was higher during shortening than during lengthening. CV measurement in vastus lateralis muscle can be applied at various knee joint angles during resting and static conditions and is needed to consider direction and angular velocity of joint movements.

P1-F-19 In-vivo measurement of the Block-Activation Window for sinusoidal Low Frequency Alternating Current (LFAC) stimulation

Michael Horn[1], Awadh Alhawwash[2], Ken Yoshida[1]
[1]IUPUI, [2]Purdue University

This work explores a modality for subtractive and/or additive modulation of the nervous system through application of a sinusoidal, low frequency alternating current (LFAC) waveform. The LFAC waveform locally elicits nerve conduction block or activation depending upon the amplitude and frequency used. Applied through bipolar cuff electrodes, LFAC first blocks conducting action potentials at low currents levels. As current is increased, the degree of block increases but then transitions to synchronous/asynchronous activation of nerve fibers. We refer to this window between the thresholds of block and activation the "Block-Activation Window." The present preliminary in-vivo work explores the effect of LFAC applied via a bipolar cuff electrode to the tibial branch of the sciatic nerve in the hind limb of an anaesthetised Sprague-Dawley rat. The prep was instrumented with two pairs of cuff electrodes on the sciatic nerve, intramuscular electrodes in the triceps surae, and a load cell at the rat's foot. LFAC block was detected by monitoring the synchronous compound muscle action potential (CMAP) and twitch force induced using standard pulse stimulation applied through the rostral cuff while increasing the amplitude of the LFAC waveform applied at the caudal conditioning cuff electrode. LFAC waveforms at 1, 2, 3, and 4 Hz were tested. As the LFAC current increased beyond the onset of block, the twitch force and peak to peak CMAP decreased until the twitch force was extinguished, the threshold of LFAC activation or the upper safe current limit reached. The current for block onset and various degrees of twitch force reduction were characterized. For activation, the LFAC waveform was presented at the caudal cuff without the rostral pulse stimulation. LFAC frequencies of at 1, 2, 3, 4, 8, and 20 Hz were tested. Activation was defined as the onset of phasic twitches or tonic contraction. Following the reflex intact trials, the sciatic nerve was crushed rostral to the rostral cuff followed by a repeat of either the block or activation protocol. Initial results indicate that block onset was observed at all block frequencies tested (1 - 4 Hz). Block was achieved without onset activation. Substantial block was possible using 1 or 2 Hz LFAC stimulation. The thresholds for various degrees of LFAC block were also found to be independent of LFAC frequency and were found to be 232 ± 49.8μA (n=4). Crushing of the nerve altered the LFAC thresholds. Unlike block, the LFAC activation thresholds were found to be frequency dependent, with the threshold decreasing with increasing LFAC frequency and ranged between 468 ± 251.3μA (n=4) and 116 ± 41.9 μA (n=5). Thus, the block activation window starts from ~232 μA at 1Hz and closes by 4 Hz. Interestingly, unlike activation using pulse stimulation, there is indication that LFAC activates fibers in an orderly size-wise order. These results concur with the predictions made in in-silico experiments of the phenomenon.

P1-F-20 Eliciting the soleus H-reflex through multi-electrode stimulation of the posterior tibial nerve: effects of the number and configuration of cathode electrodes

Markus Melvin[1], Roland Cote[1], Michael McKinnon[2], Daniel Hochman[2], Jeremy Hill[3], Jonathan Wolpaw[4], Isaac Clements[2], Aiko Thompson[1]
[1]Medical University of South Carolina, [2]Biocircuit Technologies, [3]National Center for Adaptive Neurotechnologies, [4]National Center for Adaptive Neurotechnologie

BACKGROUND AND AIM: In humans, the H-reflex, a partial electrical analog of the spinal stretch reflex, is commonly examined by stimulating a target nerve transcutaneously through a cathode/anode electrode pair. The nerve stimulation procedure can cause a level of discomfort that is tolerable for most but not all individuals. Our recent testing of multi-electrode array-based stimulation suggests that different combinations of multi-cathode stimulation can equally elicit H-reflexes, but with widely varying sensations. This finding presents the possibility of minimizing the discomfort of transcutaneous nerve stimulation through properly configured multi-electrode stimulation, which would enhance the diagnostic and therapeutic utility of H-reflex testing. Here, as the first step in testing the hypothesis that multi-electrode stimulation optimized for each individual can minimize stimulation discomfort while eliciting H-reflexes effectively, we examined the effects of the number and configuration of cathode electrodes on EMG responses and stimulus perception. METHODS: On a multi-electrode array used in this study, 13 circular cathodes (10 mm in diameter, each individually selectable) are hexagonally arranged with 15mm pitch, and a group of three individually selectable anodes (15x25 mm) are positioned 54 mm (center-to-center) above the center of the cathode cluster. This multi-electrode array was placed over the popliteal fossa for stimulating the tibial nerve in 10 adults (aged 22-58 yrs) with no known neurological conditions. EMG signal was obtained from the soleus and tibialis anterior. After carefully positioning the center of the cathode cluster at the optimum spot for tibial nerve stimulation (1-ms square pulse), the stimulus current to elicit the maximum H-reflex was determined and stimulus discomfort (i.e., pinching, stinging, lingering, and sharp) was scored for 1 single, 6 double, 6 triple, and 6 quadruple cathode configurations. For all 19 configurations, stimulus current was adjusted to maintain the size of M-wave accompanying H-reflexes, and each configuration included the central electrode. RESULTS: In all participants, for matching M-wave sizes, H-reflex sizes did not differ across different configurations. The cathode counts vs. stimulus current (producing the same size M-wave) relation varied across participants (r=0.12-0.70). The relation between the stimulus current and discomfort also varied across participants (r=-0.40-0.84). Interestingly, in 8 of 10 individuals who experienced some discomfort with single cathode stimulation, there were several multi-electrode configurations that produced less discomfort. Further, the optimal number of cathode contacts or configurations appears to differ across individuals. CONCLUSION: These observations suggest that when configured optimally, multi-electrode stimulation can minimize or eliminate stimulation discomfort while eliciting the H-reflex effectively.

P1-F-21 The effect neuromuscular electrical stimulation using the StimaWELL 120MTRS system on multifidus muscle morphology and function in patients with chronic low back pain: A pilot study

Daniel Wolfe[1], Geoffrey Dover[1], Mathieu Boily[2], Maryse Fortin[3]
[1]Concordia University, [2]McGill University Health Centre, [3]Concordia

BACKGROUND AND AIMS: Individuals with chronic low back pain (CLBP) present with multifidus muscle deficits, including decreased cross-sectional area (CSA), increased fatty infiltration and stiffness at rest compared to healthy controls. Neuromuscular electrical stimulation (NMES) is used during rehabilitation to improve muscle function, but research into the efficacy of NMES for CLBP is limited. Although multifidus deficits are associated with subjective reports of pain and disability in CLBP patients, it is unknown if treatment with NMES can help reverse these deficits. The primary aim of this preliminary study was to examine the effect of a novel medium-frequency electrotherapy device (the StimaWELL 120MTRS system) on multifidus morphology and function in CLBP patients. The secondary aim was to assess its effect on pain intensity, pain interference, disability, and catastrophizing. METHODS: This pilot study was designed to assess the effect of a progressive NMES treatment using the StimaWELL 120MTRS system. Six patients with CLBP received 20 supervised electrotherapy treatments, 2x/week, over a 10-week period. Treatment time was progressively increased up to 30 minutes. Magnetic resonance imaging (MRI) and ultrasound images were acquired at L4 and L5, at baseline and 11-week to assess multifidus muscle CSA, fatty infiltration, thickness and stiffness (shear-wave elastography) at rest and during contraction. Pain intensity (Numerical Pain Rating Scale), pain interference (Brief Pain Inventory), disability (Oswestry Disability Index), and catastrophizing (Pain Catastrophizing Scale) were measured at 3 time points (baseline, 6, and 11-week). Wilcoxon Signed Rank tests were used to assess the effect of the intervention on multifidus morphology and function, while Friedman's 2-way ANOVA by rank tests were used to assess its effect on pain intensity, pain interference, disability, and catastrophizing. RESULTS: Six participants (4 women, 2 men, 36.8±14.4 yrs old) with CLBP completed the intervention. At the end of the intervention, there was a significant decrease in multifidus CSA at L5 ($p<0.046$). There were no other significant changes in CSA, fatty infiltration, thickness or stiffness, at L4 or L5 (all $p>0.05$). Friedman's 2-way ANOVA by rank with post-hoc tests revealed statistically significance differences between baseline and 11-week scores for pain intensity ($p=0.009$), pain interference ($p=0.030$), disability ($p=0.006$), and catastrophizing ($p=0.030$). A significant decrease in ODI scores from 6-week to 11-week was also observed (Table 1). No long-term adverse effects were reported by the participants. CONCLUSIONS: This study provides preliminary evidence that a NMES intervention using the StimaWELL 120MTRS system is safe and feasible. Of note was participants' improved pain and disability, along with other pain and psychosocial outcomes following the intervention. We aim to conduct a larger scale investigation to expand our findings.

G - Fatigue

P1-G-22 Discriminant validity of fatigue indicators in stroke rehabilitation activities ? A Pilot Study

Sarah Amoura[1], Marie-Hélène Milot[2], Andréanne Blanchette[1], Alexandre Campeau-Lecours[1], Anne

Durand[3], Jason Bouffard[1]
[1]Université Laval, [2]Université de Sherbrooke, [3]CIUSSS de la Capitale Nationale

Background: Fatigue is a common symptom in individuals with a stroke (iStroke). It represents a set of processes leading to perceptual changes (perceived fatigue) and interfering with motor and cognitive (performance fatigability). Fatigue is thus often linked to reduced patient participation in rehabilitation sessions, therefore affecting the recovery of upper limb (UL) motor skills. Electromyographic (EMG) indicators have been developed to assess performance fatigability in healthy people. However, few studies have focused on the stroke population. Assessing the psychometric properties of perceived fatigue and performance fatigability indicators within this population is necessary before using them to better understand the effects of fatigue during rehabilitation. The objective of this study was to investigate the discriminant validity of perceived fatigue and performance fatigability indicators based on EMG signals during UL rehabilitation activities of individuals in the subacute phase of post-stroke recovery. Method: A person who had a stroke within 3 months of the study was recruited so far (target, 15 participants). Perceived fatigue and performance fatigability was assessed during one high intensity (T1) and one low intensity (T2 = half of T1 repetitions) rehabilitation sessions for all participants. The number of repetitions associated with an high perceived intensity (Borg between 5-7/10) was priorly estimated during a familiarization period before T1. During each session, the participant performed four UL strengthening exercises. Before and after these exercises, he performed a standardized pointing task. Performance fatigability was assessed during these pointing tasks through EMG median frequency and amplitude (Anterior [AD] and middle deltoids [MD], Upper trapezius [UT], Biceps [TB] and triceps brachii [TB]). Perceived intensity was assessed at the end of each session using the modified Borg scale. Finally, perceived fatigue was assessed after the pointing tasks and after each set of strengthening exercises using a numerical rating scale from 1 to 10. Preliminary Results: Training intensity was successfully manipulated between T1 (240 repetitions, Borg: 6/10) and T2 (120 repetitions, Borg: 1/10). Above all, perceived fatigue was reported by the participant to be greater at T1 (5/10) than at T2 (2/10). As for EMG, during T1, median frequency decreased in all muscles (-8% to -18%), except UT (-1 %) while EMG amplitude increased for AD, BB and UT (+26% to +98%; MD : -17% ; TB : +2%). At T2, EMG changes were more variable and more limited (median frequency: +4% to -7%; amplitude: -20% to +17%). Conclusion: These preliminary results suggest that performance fatiguability indicators assessed with EMG, along as perceived fatigue, are valid for assessing fatigue during rehabilitation sessions in iStroke however more data is needed to conclude on this issue.

P1-G-23 Impact of fatigue at the shoulder on the contralateral upper limb kinematics and performance

Frédérique Dupuis[1], Gisela Sole[2], Catherine Mercier[1], Jean-Sébastien Roy[1]
[1]Université Laval, [2]University of Otago

BACKGROUND Altered movement patterns have been proposed as an etiological factor for the development of musculoskeletal pain. Fatigue influences upper limb kinematics and movement performance which could extend to the contralateral limb and potentially increasing risk of injury. The aim of this study was to investigate the impact of fatigue at the dominant arm on the contralateral upper limb movement. METHODS Forty participants were randomly assigned to one of two groups: Control or Fatigue Group. All participants completed a reaching task at baseline and post-experimental phase, during which they reached four targets with their non-dominant arm in a virtual reality environment. Following the baseline phase, the Fatigue Group completed a shoulder fatigue protocol with their dominant arm only, while the Control Group took a 10-minute break. Thereafter, the reaching task was repeated. Upper limb and trunk kinematics (joint angles and excursions), spatiotemporal (speed and accuracy) and surface electromyographic (sEMG) activity (sEMG signal mean epoch amplitude and median frequency of the EMG power spectrum) were collected. Two-way repeated-measures ANOVA were performed to determine the effects of Time, Group and of the interaction between these factors. RESULTS There was a significant Time x Group interaction for sternoclavicular elevation range of motion (p=0.040), movement speed (p=0.043) and accuracy (p=0.033). The Fatigue group showed higher contralateral sternoclavicular elevation and increased their movement error while experiencing fatigue in the dominant arm. Moreover, the Control group increased their speed during the Post-experimental phase compared to baseline (p=0.043), while the Fatigue group did not show any speed improvement. There was no EMG sign of fatigue in any of the muscles evaluated. CONCLUSION This study showed that the central component of fatigue impacts movement at the contralateral upper limb. Such changes may be a risk factor for the development of shoulder pain in both the fatigued and non-fatigued limbs.

P1-G-24 Central and peripheral fatigue induced by a sustained isometric contraction are not different between young healthy males and females for ankle plantarflexor muscles.

Donguk Jo[1], Miriam Goubran[1], Martin Bilodeau[1]
[1]*University of Ottawa*

BACKGROUND AND AIM: Sex-related differences in neuromuscular fatigue have been reported in several studies, with males typically showing greater performance fatigability than females. However, such differences are not consistent across muscle groups and tasks and have not been thoroughly documented in human plantar flexors. Differences in performance fatigability between males and females could be explained by differences in the function of various mechanisms within central and peripheral structures of the neuromuscular system. The main aim of this study was to determine sex differences in central and peripheral fatigue produced by a sustained isometric exercise of ankle plantar flexors in healthy young adults. METHODS: Ten males and fourteen females (mean age 28.3 years) were asked to sustain 30% of their bilateral maximal voluntary isometric contraction (MVIC) torque in ankle plantarflexion until task failure. MVIC plantarflexion torque, voluntary activation level (reflecting 'central fatigue', using the twitch interpolation technique), and twitch contractile properties (reflecting 'peripheral fatigue': twitch peak torque, twitch half relaxation time, and low frequency fatigue (LFF) ratio) were measured before, immediately after, and throughout a recovery period (1, 2, 5, and 10 min) following the exercise protocol in order to characterize neuromuscular fatigue. Mixed-model analyses of variance (ANOVAs) and multiple regression analyses were used to assess the effect of sex, fatigue and their interaction on variables reflecting central and peripheral neuromuscular function, as well as the contribution of central and peripheral mechanisms to performance fatigability, respectively. RESULTS: The fatigue task was found to have a significant effect ($p < 0.05$) on all dependent variables. However, we found no significant sex X fatigue interaction for any of the central and peripheral fatigue variables. Also, similar performance fatigability (reduced MVIC torque and time to task failure) was found between males and females. The regression analyses showed that changes in voluntary activation and twitch peak torque both contributed to the pre-to-1 min post-exercise change in MVIC torque (no contribution of sex), whereas only voluntary activation showed a significant contribution to the MVIC torque change in males when sex groups were analyzed separately. CONCLUSIONS: Overall, similar performance fatigability as well as fatigue mechanisms were found between males and females. This could be explained by the relative lesser sex differences in contractile function and proportional area of type I fibers of ankle plantar flexor muscles compared with other muscle groups.

P1-G-25 The Effects of Alternating Computer Work Postures on Upper Trapezius Muscle Activity, Discomfort and Performance

Samuel Lamanuzzi[1], Erika Renda[1], Julie Côté[1]
[1]*McGill University*

BACKGROUND AND AIM: To reduce musculoskeletal disorders (MSDs) during computer work, some have advocated using postures other than sitting, such as standing, while working with a computer. Although many studies have compared health outcomes and mechanistic exposures of standing and seated postures, few have quantified impacts of alternating these postures on electromyographic (EMG), computer performance or discomfort outcomes. The objective is to compare seated, standing, and alternating sitting and standing postures, on biomechanical, performance and symptom characteristics associated with performing a standardized computer typing task. METHODS: Twenty-four healthy young adults (12 males) are recruited to complete three separate 60-minute computer tasks, involving reading and typing, in postures of either seated, standing, or alternating between the two (15 minutes of seated computer work followed by 15 minutes of standing computer work)[1]. Upper Trapezius activity was recorded using surface EMG electrodes (Delsys©). Visual analog scales measured visual, neck/shoulder and lower back discomfort, while computer performance was measured by number of words per minute with the Mavis Beacon Teaches Typing software. Root-mean-square (RMS) EMG values were calculated for data recorded every 5 minutes, along with discomfort and computer performance measures. Repeated measures analysis of variance assessed main and interaction effects of Time and Condition (seated, standing, alternating postures). RESULTS: Preliminary results ($N = 11$) show that there was significant Time × Condition interaction effect on EMG ($p = 0.03$). Standing displayed the lowest RMS values, while seated displayed the highest, with alternating computer work somewhere in between. For visual discomfort, there was a significant Time × Condition interaction ($p < 0.001$). For neck/shoulder discomfort there was a significant main effect of Time ($p < 0.001$). For lower back discomfort there was a significant interaction effect of Time × Condition ($p = 0.002$). All discomfort rating increased throughout time, with alternating computer work displaying the lowest discomfort ratings. Finally, there were no significant main or interaction effects on computer performance. CONCLUSIONS: Results suggest that: 1) during alternating computer work postures, individuals modify their muscle use through time depending on whether they were seated or standing, 2) alternating between sitting and standing can reduce visual and lower back discomfort experienced during seated computer work throughout time but has no effect on reducing neck/shoulder discomfort, and 3) alternating between sitting and standing has no detrimental effects on computer performance. 1. Callaghan et al. (2015). Ergonomics in Design, 23(3), 20- 24.

P1-G-26 The effect of concurrent mental and physical fatigue on physical endurance performance and strength

Rahul Pabla[1], Jeffrey Graham[1], Nicholas La Delfa[1]
[1]*University of Ontario Institute of Technology (Ontario Tech)*

BACKGROUND AND AIM: Significant research focus has been dedicated to understanding the independent effects of either physical or mental fatigue on performance; however, their interactive effects on physical performance has been relatively underexplored. As such, the purpose of this study was to evaluate the independent and interactive effects of mental and physical fatigue on handgrip endurance time and strength, compared to just mental fatigue and muscle fatigue elicited independently. METHODS: At this stage of data collection, 4 of a planned 20 participants (3M, 1F) between the ages of 18-35 have been recruited. Participants visited the lab on four separate days to complete each experimental condition in a counter-balanced order. In each session, participants performed two maximum handgrip voluntary contractions (MVCs) and two isometric handgrip endurance trials (at 50% MVC) until exhaustion, separated by an experimental manipulation. The manipulations consisted of one of four conditions completed for 15 minutes each: physical fatigue (intermittent handgrip contractions at 15.3% MVC and a 50% duty cycle), mental fatigue (mental arithmetic), concurrent fatigue (intermittent handgrip and mental arithmetic) and control (watched a documentary). Note: Surface EMG (from wrist flexor and extensor muscles) and force tracing performance data were also recorded, but not presented in this abstract. RESULTS: Initial findings show that the largest change in endurance time was observed for the physical fatigue condition (7.9% reduction), followed closely by the concurrent fatigue condition (7.7% reduction). The mental and control conditions showed marginal decreases in endurance time (3% and 2%, respectively) between pre-post endurance trials. Strength (i.e., handgrip MVC) was also affected similarly by the experimental manipulations, with the largest pre-post difference observed for the concurrent fatigue condition (14% decrease), followed by the physical fatigue condition (10% decrease). Whereas the control and mental fatigue conditions resulted in minimal 2% increases in MVC values. CONCLUSIONS: Despite a very limited sample size at this stage, initial findings provide support for the negative effects of concurrent mental and physical fatigue on handgrip endurance and strength, when compared to these exposures in isolation. Though a similar reduction in endurance time was found relative to physical fatigue alone, an additive fatigue effect was observed for strength in the concurrent condition. These deficits in endurance time and strength could potentially be explained by higher perception of effort, increased accumulation of adenosine in the anterior cingulate cortex or an alteration of motor recruitment patterns. This work can have important implications in occupations involving both physically and mentally demanding work (e.g., surgery, dentistry) and can help guide recommendations to limit work-related musculoskeletal injuries under these conditions.

I – Motor Control and Motor Learning

P1-I-27 Methodological Analysis of Finite Helical Axis Behaviour to Assess Trunk Motor Variability during Repetitive Movements

Amal Alsubaie[1], Corrado Cescon[2], Eduardo Martinez-Valdes[1], Marco Barbero[2], Deborah Falla[1]
[1]*Centre of Precision Rehabilitation for Spinal Pain (CPR Spine), School of Sports, Exercises and Reha,*
[2]*Rehabilitation Research Laboratory 2rLab, Department of Business Economics, Health and Social Care,*

Introduction: The high level of repeatability in activities of daily living as well as in occupational settings shows the importance of motor variability. The helical axis (HA) of motion is one of the recently proposed approaches to functionally investigate three-dimensional joint kinematics since joint movements usually involve rotation of one body segment relative to another. However, the axis of rotation of one segment in relation to another are not usually fixed, but vary in orientation and position due to the different shapes of joint surfaces and the variability of muscle activation. The HA method can estimate this unique orientation and position for each axis of motion that is created with each cycle of motion. To date there has been no attempt to describe the trunk HA during movement without the need of a 3D reconstruction of the bones of the joint. Therefore, the aim of the study is to describe the dispersion of HA parameters in healthy individuals during repetitive trunk movements. Methods: Twelve asymptomatic volunteers were enrolled in this study. The three-dimensional movements of the spine were captured using seven infrared cameras to track 14 markers attached on the skin along the subject's spine. The markers were placed to define three spinal segments: thoracic, lumber, and sacral segments. From a sitting potion, participants were asked to perform 30 continuous cycles of repeated trunk (flexion/extension, bilateral rotation, and bilateral side bending) at three different speed levels; slow (30 beats per minute), fast (50 beats per minute) and a self-selected speed. To standardise the trunk range of motion between participants, they were asked to reach four targets guided by a laser pointer attached to their sternum. Upper and lower targets for trunk flexion and extension movements were 35^o and 15^o respectively. Right and left targets for the rotation movements were set at 30^o while for side bending the target was set at 15^o. Although all movement cycles of each trial were recorded, only the middle 15 cycles were analysed with the HA technique to ensure steady-state movement behaviour. Two parameters were extracted for the three spine segments during repetitive movements: mean angle (MA) and distance of their center from the segment (MD). Results: Significant within-subject effect of movement plane of motion ($p<0.05$) was observed for (MA) but no effect was observed for (MD) except between the thoraco-sacral segments were a significant difference was found. No within-subject effect of movement speed on the HA parameters was observed. Based on the parameters of the HA, the thoraco-lumbar region had a larger MA compared to the lumbo-sacral area and thoraco-sacral regions (Table1). Discussion and Conclusion: This novel method of analysing the kinematic variability of the spine shows higher variability between the thoraco-lumbar segments, which is sensitive to change in the direction of motion rather than movement speed. The HA could be used in future studies to describe trunk motor variability of people with low back pain.

P1-I-28 Difference of Influence of Intermittent Blocking of Visual Information on Walking Parameters and Cortico-muscular Coherence

Hitoshi Makabe[1], Ai Ogawa[2], Misuzu Awano[3], Kenichi Kaneko[4]
[1]Juntendo University, [2]Shin-yurigaoka General Hospital, [3]Shonai Amarume Hospital, [4]Fuji University

BACKGROUND AND AIM: Automaticity of walking is a feature in healthy and well-functioning adults. However, it is unclear how the automaticity of walking will be affected when visual information is interrupted intermittently. Therefore, the purpose of this study was to clarify the difference of influence of intermittent blocking of visual information on walking parameters and cortico-muscular coherence (CMC) in healthy young and old persons. METHODS: Twelve healthy young persons (age: 21.2 ± 0.8 years) and twelve old persons (age: 70.6 ± 3.2 years) living in the community participated in this study. Subjects walked a 20m 8-shaped walking path at a comfortable speed for 10 minutes. Measurement conditions were the following three conditions. The liquid crystal shutter goggle blocked the subjects' visual information with 10 Hz blinking frequency under two conditions with 30% and 70% duty ratios. The control condition did not block visual information (without the liquid crystal shutter goggle). Walking parameters of speed, walking rate, and step length were evaluated above the three conditions. Electroencephalogram (EEG) and electromyogram (EMG) were measured during walking using a 4-channel Ganglion Board (Open BCI) at the 200Hz sampling frequency. EEG activity was recorded through unipolar silver electrodes placed at Cz by the international 10-20 system. Surface EMG electrodes of Ag/AgCl (Kendal H124SG, 30mm×24mm, interelectrode distance 2cm) were placed at the proximal 1/3 of the tibialis anterior (TA) muscle of the right leg. EEG and EMG electrode impedances were kept below 5k Ohm. The Welch algorithm calculated EEG-EMG coherence (Cz-TA coherence) for Cz-TA in theta (4-

8Hz), alpha (8-13Hz), beta (13-30Hz), and gamma (30-40Hz) bands (window width: 256 points, overlapping 128 points, resolution 0.78 Hz). Walking parameters and peak values of Cz-TA coherence in the four bands were evaluated in the above three conditions. Using repeated-measures ANOVA, the evaluation parameters compared no blocking and intermittent blocking with 30% and 70% duty ratios. Statistical significance was given for P-values smaller than 0.05. RESULTS: There was no significant difference in walking parameters during intermittent blocking of visual information with 30% and 70% duty ratios in young and old persons. The peak value of Cz-TA coherence in the beta band significantly decreased in young persons at intermittent blocking of visual information with the duty ratio of 70% compared to that of no blocking. On the other hand, the peak value of Cz-TA coherence in the beta band with the duty ratio of 30% and 70% in old persons significantly increased compared to that of no blocking. CONCLUSIONS: The peak value of Cz-TA coherence in the beta band decreased significantly in young persons and increased significantly in old persons under intermittent blocking of visual information. The difference was considered to have arisen from attentional demands during walking. Therefore, the peak value of Cz-TA coherence in the beta band might be a useful index for evaluating the attentional demands of walking.

P1-I-29 Both hands EMG activity at cooking work between student and instructor

Kimie Nakajima[1], Takeshi Sato[2], Mizuki Nakajima[2], Miyu Kayama[3], Kenichi Egawa[1]
[1]Tokyo Kasei Gakuin University, [2]Jissen Women's University, [3]Junior College of Kiryu

Bilateral hand cooperation control is an essential function of the upper extremities and plays an important role in the activities of daily living (ADLs). Additionally, inter-limb coordination is an important function of cooking because it enables the individual to hold objects with one hands and the other hands preparation cutting the food from the both hands. However, the nutrition education focuses more on nutrients and recipe development than on cooking procedures. It was not enough data about cooking skill of movement to compare between student as a novice and instructor as a registered dietitian. Aim: Previous studies addressing the transfer of motor learning between hands also identify a principal role for the basically motor learning. Therefore, the purpose of this study were to investigate skill-related changes in coordination control of the both hands and the motor learning as cooking performance of the omelet in nutritional education.Methods:Two healthy female adults participated in the experiment after giving their informed, consent following the protocol approved by the Jissen Wormen's University ethics review board (H2021-04). For the cooking behavior task, it was made an allergy-friendly omelet and then made a regular omelet for each subject. All participants were right handed, as determined by the Edinburgh Handedness Inventory. The movement of body segments were identified using 10-mm diameter reflective markers and captured by web camera (C992n, logicool), and upper arm muscle activities were acquired using a wireless surface EMG system (Polymate, Miyuki Giken) at sampling rates of 500 Hz. The skin around the 4 identified placements of surface electrodes was cleaned using alcohol to remove dirt, oil and dead skin, as well as shaved if necessary to reduce resistance during the EMG acquisition of muscle activities, both brachial radial muscle and biceps brachii muscle. Raw EMG signals were full-wave rectified to calculate for integrated EMG, iEMG, respectively.The results demonstrated that novice student took 1.6 times, over 2000 seconds as long to complete the cooking omelet tasks as an instructor. Comparing the EMG activity as iEMG was significant smaller at dominant arm muscles in an instructor. Future coherence analyses explored each rectified EMG activity with mean-smooth filtered, EMG coherency of the left and right radial muscles averaged 0.93 for the instructor and 0.25 for the novice student during the entire cooking tasks. Conclusion:It was found evidence for skilled person as registered dietitian, performed cooking task quickly and accurately in the effect of occupational experience. Our results point to the food processor, it was almost same period at working time between instructor and student. The results of coherency indicate that novice student in unstable and poor

P1-I-30 Effects of Static Head Position on Unintentional Body Rotation and Displacement During Stepping in Place Without Vision

Flavia De Andrade e Souza Mazuchi[1], Lucas Michaud[1], Nicole Paquet[1]
[1]*University of Ottawa*

BACKGROUND AND AIM: When stepping in place without vision (SwV), most healthy individuals unintentionally turn and move away from their starting position [1]. The final position at the end of the stepping trials was found to be modified by unilateral neck muscle vibration [2], likely because neck proprioceptive inputs are part of the self-motion cues involved in spatial orientation [3]. Since these proprioceptive inputs are modulated by the static position of the head, the question arises as to whether the static head position could modify the body rotation and linear displacements. In a past study, no difference in the final body rotation was found between maintaining the head in right or left rotation [2]. Little is known, however, on the impact static head position may have on linear displacements, i.e., medio-lateral (ML) and antero-posterior (AP) displacements. The aim of this study was to determine the effects of four static head positions on body rotation, and ML and AP displacements in the SwV task. METHODS: Nine participants (27 ± 4 years, 6 women) were blindfolded and performed the 50-step task with the head maintained in left rotation (LR), right rotation (RR), up rotation (UR) or down rotation (DR). Four trials of each condition were done in a random order. Reflective markers were placed on the head and on the heels, big toes and shoulders. Kinematic data were recorded with the Vicon512TM system at 200 Hz. Body rotation was the final angle of a line connecting the two shoulders. Trajectory deviation (ML displacement) and AP displacement were obtained from the final X-Y position of a middle point between the two big toes. Negative values indicate a leftward rotation or deviation. Dependent variables were compared between the LR and RR conditions and between the UR and DR conditions with paired t tests. RESULTS: For LR and RR, the head was maintained at a mean horizontal rotation of -49° (SD 10°) and 49° (SD 12°), respectively. At LR, the mean body rotation (-2°, SD 33°) was significantly smaller than at RR (-20°, SD 37°; $t(33) = 2.86$, $p < 0.01$), but the mean ML displacement was not different between LR (-9.1 cm, SD 34.3) and RR (-15.0 cm, SD 37.3; $p > 0.05$). For UR and DR, the head was maintained at a mean vertical rotation of 28° (SD 9°) and -50° (SD 11°), respectively. The mean AP displacement was not different between UR (54.4 cm, SD 34.0) and DR (51.3 cm, SD 40.4; $p > 0.05$). CONCLUSIONS: We found that the static horizontal head rotation modified the unintentional body rotation and that maintaining the head in RR induced a leftward body rotation, on average. The results support that neck proprioceptive inputs are involved in spatial orientation when the visual cues are absent, and that they are specifically involved in the control of angular body movement during SwV. REFERENCES: [1] Fukuda, Acta Otolaryngol, 1959;50:95-108. [2] Bove et al, J Neurophysiol, 2002;88:2232-41. [3] Wolbers & Hegarty, Trends Cog Sci, 2010;14:138-46.

P1-I-31 On the origin of triceps surae EMG activity increase in response to increased walking speed and loaded weight

Bridgette Pouliot[1], Aiko Thompson[1]
[1]*College of Health Professions, Medical University of South Carolina*

BACKGROUND: Previous studies have indicated that proprioceptive afferents Ia, II, and Ib contribute differently to the stance phase soleus activity in human locomotion (J Physiol 2000;523:817-827; J Neurophysiol 2005;93:167-177). To further our understanding of afferent contribution to generation and modulation of locomotor EMG activity, here we investigated the stance phase soleus and lateral gastrocnemius (LG) H-reflexes and EMG activity at different walking speeds with different weight bearing conditions. METHODS: To ensure the robust impact of fixed weight and speed conditions, all participants were young women of similar physical size (27±6 yr, 163±4 cm, 65±9 kg) with no history of neurological or orthopedic injury. Each participant walked on the treadmill at 1.0 and 1.5 m/s with or without an additional 20.4 kg, which was worn as a set of weighted belt and vest, either on the front or back of the body. During each of the six (1.0 and 1.5 m/s speeds x none, front, and back weight conditions) ~10-minute treadmill walking bouts, the soleus and LG locomotor EMG and H-reflexes, ankle, knee, and hip joint motion, and ground reaction force (GRF) were measured. RESULTS: The mid-late stance (i.e., 35-50% of gait cycle) EMG amplitude with 1.5 m/s was nearly 200% of that with 1.0 m/s: 178-193% for soleus and 195-214% for LG. The late stance H-reflexes were also larger with 1.5 m/s than with 1.0 m/s but to a lesser extent (+12-30%). Late stance ankle dorsiflexion (DF) was ~5° less with 1.5 m/s than 1.0 m/s, but leading up to late stance, DF speed over 35-45% of gait cycle did not differ between the two speeds. Over the same period (i.e., 35-45%) of gait cycle, GRF developed rapidly with 1.5 m/s: rate of force development (RFD) was 2-3x higher with 1.5 m/s than with 1.0 m/s, suggesting the occurrence of enhanced loading with 1.5 m/s during this phase. Added weight reduced DF speed by -5-11 º/s across both speeds, and increased RFD by ~100 N/s at 1.0 m/s. There was no significant effects of weight on H-reflexes ($p>0.05$). Overall, speed and weight affected the step cycle duration (~230 ms difference across conditions) but produced only minor effects on hip and knee joint motion in the mid-late stance phase. CONCLUSIONS: Walking speed has significant impact on plantarflexor activity in the mid-late stance phase. Small increases in H-reflex amplitude relative to ongoing EMG activity, together with robust increases in RFD and reductions in DF, observed during 1.5 m/s walking support a possibility that load-sensitive afferents, not muscle spindle afferents, play a major role in increasing plantarflexor activity in response to increasing gait speed. To better assess the effects of added weight, further analyses are currently underway.

P1-I-32 Inability to suppress physiological mirror activity during sustained and discrete maximal unilateral handgrip contractions

Doug Renshaw[1], Jason DeFreitas[2], Shawn Reese[3], Rob Maclennan[2], Jonathan Farthing[1]
[1]University of Saskatchewan, [2]Oklahoma State University, [3]Oklaoma State University

BACKGROUND AND AIM: Physiological Mirror Activity (pMA) describes the involuntary muscle activity in the contralateral homologous muscle during unilateral movements. The magnitude of pMA is positively correlated with the functional requirements of the task including voluntary force production as well as central and peripheral fatigue. The purpose of this study was to test participants' ability to cognitively suppress pMA during 60s maximal effort handgrip contractions compared to time-under-tension matched, maximal effort discrete contractions. We hypothesized that maximal, sustained contractions would lead to greater pMA than time matched discrete contractions, even while trying to suppress the pMA. METHODS: Seventeen healthy participants (6 female; age: 26.7±3.8 yrs) visited the lab on 3 separate days, at least 48h apart. Participants completed the same unilateral tests each day for the right and left hand, with day 1 as familiarization and day 2 as baseline, but for day 3 participants were instructed and reminded, at regular intervals, to relax the inactive limb (i.e., suppression). On all testing days, participants had handgrip force and EMG recorded from bilateral wrist flexor and extensor muscles. After completing three, 3 s handgrip maximal voluntary contractions (MVC) for each hand, participants completed two conditions for each hand in random order, separated by 5 min of rest between conditions and 10 min of rest between hands: 1) a 60s sustained maximal handgrip contraction; and 2) four sets of five discrete handgrip contractions (3 s on: 3 s off with 2 min rest between sets; 60s total contraction time). pMA was normalized to EMG during the MVC trials and data was extracted from each condition at 5 matched time epochs for comparisons. RESULTS: RMANOVA for pMA revealed a significant Condition × Time interaction, $F_{GG}(2.1,33.0)=17.2$, $p<.001$, $\eta p2=0.52$; post hoc tests showed greater pMA at Epoch 4 and 5 for the sustained compared to the discrete condition (9.6% vs 5.8% and 11.3% vs 5.4%, respectively; $p<.001$) with no differences for the first 3 epochs. There were no differences in pMA between days for either condition. RMANOVA for active limb force revealed a significant interaction between Condition and Time, $F(4,64)=72.7$, $p<.001$, $\eta p2=0.82$; post hoc tests showed persistent decreases in force at all 5 epochs during sustained, but only for epoch 2 for discrete conditions. The sustained and discrete conditions were accompanied by an average force decline of 49.6% and 18.4% in each active limb, respectively. CONCLUSION: These data support the hypothesis that participants would be unable to cognitively suppress pMA during sustained maximal effort contractions. While there was no appreciable difference in pMA in the discrete condition, there was a near three-fold increase of the pMA as the sustained condition persisted.

P1-I-33 Proprioceptive contribution to motor learning in an elbow flexion-extension task

Martin Vaurs[1]
[1]Université de Poitiers

Introduction Proprioception has been suggested to be a key component of motor learning, i.e. the ability to adjust motor performance based on feedback relative to prior execution (Krakauer et al. 1999). However, proprioceptive influence on motor learning has been mostly investigated in short-term (< 2h) adaptations, limiting the understanding of possible long-term (≥24h) effects (Vidoni & Boyd 2008). Our objective was to identify whether proprioceptive feedback contribute to long-term motor learning. We hypothesized that vibrating muscle tendons would be detrimental to a long-term motor learning performance. Method Ten healthy young adults (4 women, 22 yo) reproduced a continuous motion of elbow flexion-extension (70° maximum amplitude, duration of 3.5 s), with their right arm secured in a mechanical device and hidden underneath a blanket. Five participants were equipped with tendinous vibrators on the biceps and triceps distal tendons (VIB group) and five were not (control, CTL group). In the VIB group, tendons were vibrated at 5 different frequencies (from 50 to 90 Hz), randomly presented. All participants performed an acquisition phase of 10 blocks with 10 trials each, and a retention block of 10 trials 24h later. The elbow angle time history was recorded and, along with the reference angle time history, was displayed to participants at the end of each trial, for 5s. No visual feedback was provided during the trial. RMSE computed between the two time histories were compared using a two-way ANOVA ("Group" and "Block" as factors). Cohen d-tests were used as post-hoc. Results Mean RMSE decreased of about 5 to 15° between block 1 and block 10, in both groups. Statistical analysis revealed a significant effect of both factors and a significant interaction. Post-hoc comparisons revealed that RMSE in block 1 was superior to all other blocks, in both groups. Only in block 1, the RMSE in the CTL group was superior to the RMSE in the Vibration group. RMSE in the retention blocks were both inferior to the RMSE measured in block 1, but were not different between groups. Conclusion Motor learning occurred despite alteration of a proprioceptive feedback. Contrary to our hypothesis, participants of the VIB group adapted better to the task than the CTL group but in the 1st block only. This suggests the task may have been too easy to learn and/or that vibration may have increased attentional focus towards proprioceptive feedback. Another hypothesis would be to focus on dynamic feedback disruption instead of kinematic feedback (Krakauer et al. 1999). Further research is necessary to disentangle whether proprioceptive feedback contribute to long-term motor learning. References Krakauer J.W., Ghilardi M.F., Ghez C. 1999. Independent learning of internal models for kinematic and dynamic control of reaching. Nat neurosci, 2:1026-1031. Vidoni E.D., Boyd L.A. 2008. Motor sequence learning occurs despite disrupted visual and proprioceptive feedback. Behav & Br

P1-I-34 Influence of lumbar alignment and masseter muscle activity during stance posture on forward stepping motion

Keio Ishiguro[1], Shunsuke Adachi[1], Mizuki Saito[1], Manaka Baba[1], Yoshinobu Hosoya[1], Tomoki Ishimori[1]
[1]*Tokyo University of Technology*

BACKGROUND ADM AIM: The purpose of this study was to clarify the effects of lumbar spine alignment and masseter muscle activity on the reaction time of the forward stepping motion when the subject was in the so-called stance posture in the standing position. METHODS: Ten healthy male university students aged 21 to 22 years old without any orthopedic diseases or walking disabilities participated in this study. Prior to commencing the study, the aims and methods of the study were explained to the participants and their consent was obtained. The task was to take a 70 cm step forward from a stance with the hip and knee joints flexed at 30 degrees (stance posture). We analyzed whether there was a difference in the reaction time of the movement when taking a step under these four conditions: lumbar lordosis and kyphosis, with and without contraction of the moderate masseter muscle. The frame of analysis was from the time the LED light was turned on to the time the stepping foot landed and the vertical component of the floor reaction force reached 100% of the body weight. The time required for the movement was divided into reaction time and movement time, and these times added together was defined as response time. The movements were measured using a 3D motion analysis system, Vicon-Nexus, and floor reaction force plates. Muscle activity of the masseter, erector spinae, gluteus maximus, quadriceps femoris, biceps femoris, gastrocnemius, and tibialis anterior muscles were measured using the surface electromyograph Delsys-system at a sampling rate of 1,000 Hz and were processed as the rate of rms-EMG according to the volume ratio of the maximum voluntary contractions of each muscle. Statistical analysis was performed using a two-way ANOVA with a risk ratio of 5% for the movement time and the EMG data between each condition. RESULTS: There was no significant difference in the movement reaction time and the activity of all muscles between the conditions. A moderate correlation was found between the response time and the position of center of pressure (COP) in the sagittal plane (Fig. 1). CONCLUSIONS: In conclusion, in the stepping-out movement, although the movement time varied among the conditions, the results suggest that the time required for the fast movement is strongly related to the COP position in the sagittal plane when the LED light is turned on.

J – Motor Disorders

P1-J-34 Limits of stability and postural control stability in children with learning disorders.

Sirine Guetiti[1], Geneviève Cadoret[1], Mariève Blanchet[1]
[1]*UQAM*

BACKGROUND AND AIM: Some studies indicated that children with learning disabilities have sensorimotor deficits that interfere with their performance during school tasks. However, it is unclear

whether these neurodevelopmental disorders have a negative impact their stability limits (SL). Objective: To examine stability limits (SL) and postural control stability during maintain of SL in different sensory conditions in children with learning disabilities. METHODS: We compare center of pressure (COP) displacements during SL of children with LD (n=26) to those of typical children (n=20) (9-13 years old). Children stood on an AMTI force plate, arms crossed on the chest. Children were asked to lean as far as possible in forward, backward, rightward and leftward during 10 sec. Two sensory conditions were tested: 1-eyes open and 2-eyes closed, standing on a foam. RESULTS: The statistical analysis conducted on variables measured during the last 5 sec. of maintaining maximal leaning posture revealed that LD children had larger COP root mean square amplitude compared to typical children, suggesting that LD children had stability impairments. Furthermore, LD groups had significantly smaller maximal COP excursion than typical children indicating that they had smaller SL. CONCLUSIONS: LD children had postural control impairments. That could interfere with children's performance during daily and physical activities and even negatively impact social inclusion.

P1-J-35 Alteration of sensorimotor integration mechanisms in presence of subacromial impingement syndrome.

Lydiane Lauzier[1], Louis-David Beaulieu[1], Stéphane Sobczak[2], Mathieu Boudier-Revérêt[3], Laurence Munger[1]
[1]UQAC, [2]UQTR, [3]CHUM

BACKGROUND: More than 2/3 of the population will suffer from shoulder pain, for instance caused by an impingement syndrome (IS),that persist more than 3 years in up to 50% of cases. An IS often presents with an altered proprioception (movement sense) and control over the superior trapezius (ST) and scapular muscles during shoulder elevation. However, neural mechanisms involved in these sensorimotor alterations remain understudied. OBJECTIVE : Investigate the integrity of mechanisms involved in proprioceptive processing and motor control of shoulder elevation in the presence of an IS. METHODS : 20 participants with chronic IS, confirmed with ultrasound and pain provocation tests, and 20 age/gender-matched healthy participants will take part in 1 experimental session. The primary outcomes are measures of primary motor cortex (M1) and corticospinal excitability using transcranial magnetic stimulation (TMS) over ST's M1 representation (both hemispheres will be tested). Secondary outcomes include validated clinical scales of shoulder proprioception, as well as vibration-induced kinesthetic illusions (VIB-KI). TMS will also be used during VIB-KI to evaluate M1's processing of proprioceptive afferents. ANTICIPATED RESULTS: Motor cortical excitability, shoulder proprioception and M1 processing of VIB-KI will be altered in the shoulder affected by IS, and probably to a lesser extend in the contralateral shoulder as well considering the systemic impact of chronic pain on neural function. CONTRIBUTION : This project will help gaining a better understanding of mechanisms involved in alterations of shoulder sensorimotor function in people with IS, and open up new sensory-based therapeutics approaches.

P1-J-36 Parkinson's disease with freezing of gait alters the influence of the posterior parietal cortex on the tibialis anterior muscle

Frédérike Parent-L'Ecuyer[1], Alexandra Potvin-Desrochers[1], Alejandra Martinez Moreno[1], Julien Clouette[1], Henri Lajeunesse[1], Freddie Seo[1], Gleydciane Alexandre Fernandes[1], Audrey Parent[1], Alexander Fulford[1], Michelle Cheng[1], Caroline Paquette[1]
[1]McGill University

BACKGROUND AND AIM: The posterior parietal cortex (PPC) is a brain region that contributes to the planning of locomotion by integrating sensorimotor information. Dual pulse transcranial magnetic stimulation (TMS) can be used to assess the influence of PPC conditioning on cortical excitability of the primary motor cortex (M1). Functional and structural alterations in the PPC were identified in people with Parkinson's disease who have the freezing of gait symptom defined as the inability to step forward despite the intention to walk. FOG is a prevalent motor symptom of Parkinson's disease, and it significantly increases risk of fall. Quantifying the effect of the PPC on cortical excitability of motor representations of the muscles involved in locomotion is thus paramount. The aim of this study was to quantify the effects of conditioning the PPC on the cortical excitability of the motor cortex representation of the TA in freezers and compare its effects to healthy participants. METHODS: Preliminary data in 10 adults with FOG (7 males, mean age ± standard deviation (SD) 66 ± 13 years) were obtained. The study consisted of 3 sessions with participants in the ON-medication state. Single-pulse TMS was applied over the TA hotspot. The stimulator intensity was adjusted to produce a response average of 1mV. Dual-pulse TMS was applied over the PPC (x=-52, y=-49, z=47) at 90% of the resting motor threshold of the first dorsal interosseous muscle, located at similar depth as the PPC, 4ms prior to TA stimulation. For the healthy group, pilot data from 4 healthy adults (1 male, mean age ± SD 33 ± 10 years) were collected from a different study using the same stimulation protocol, but collected in one session only. For both groups, 25 single pulse trials were applied targeting the TA hotspot only and 25 dual pulse trials were applied to both PPC and TA hotspots for each session. All pulses were delivered randomizing single and dual pulse stimulations. The effect of the PPC on the TA was quantified by comparing single and dual pulse TMS of the peak-to-peak amplitude of the motor evoked potential (MEP) of the TA. RESULTS: Preliminary data analyses show that in the FOG group, stimulation of the PPC with TMS significantly increased cortical excitability of TA (mean change ± SD 11 ± 26%, P<.05). However, in the healthy group, stimulating the PPC did not significantly inhibit the cortical excitability of the TA (mean change ± SD -21 ± 21%, P=.14). CONCLUSION: Our preliminary results show that in freezers, the PPC does not have the same effect on the excitability of the M1 of the TA it has in healthy individuals. While in healthy participants activation of the PPC with dual-pulse TMS has an unsignificant inhibition effect on the TA motor cortex, our preliminary findings suggest that there is an excitation effect in FOG. This suggests that freezers may have impaired connectivity between the PPC and the TA motor representation.

K – Motor Units

P1-K-37 The tendency for sustained motor unit discharge is increased at short muscle lengths in the human lower limb

James Beauchamp[1], Obaid Khurram[1], Julius P A Dewald[1], CJ Heckman[1], Gregory E P Pearcey[2]
[1]Northwestern University, [2]Northwestern University/SRALab

BACKGROUND AND AIM: The coordinated discharge of motor units (MUs) required for voluntary movement arise from the net action of excitatory, inhibitory, and neuromodulatory commands to motoneurons. A central component of these neuromodulatory commands are voltage sensitive persistent inward currents (PICs), which act to amplify and prolong excitatory synaptic input to motoneurons. The magnitude of these PICs are both facilitated by descending monoaminergic input while also being uniquely sensitive to inhibitory input, which provides potential mechanisms for sculpting the neuromodulatory actions of PICs to meet a variety of task demands. Indeed, reciprocal inhibition, from stretching of the antagonist muscle with changes in joint angle, has been shown to

attenuate PICs in the decerebrate cat and could be responsible for changes in MU excitability across joint angles. If this relation remains in the human model with static changes in ankle joint angle is unclear, where both mechanical and neurophysiologic changes (i.e. muscle length and reciprocal inhibition) may influence the neuromodulatory actions of PICs. METHODS: To investigate the neuromodulatory action of PICs at various joint angles, neurologically intact human participants (N=13) performed isometric plantarflexion and dorsiflexion contractions with the ankle held in either a dorsiflexed or plantarflexed position (70º or 110º ankle flexion). High-density surface electromyography was collected from the tibialis anterior, medial gastrocnemius, and soleus with MU spike trains estimated via convolutive blind source separation. Tasks included traditional ramp contractions and a novel "sombrero" paradigm comprised of a triangular contraction superimposed upon a steady low-level contraction. The sombrero task demands two plateau regions of identical motor output before and after a triangular contraction, which allows for characterization of MUs that are recruited by additional synaptic input in the triangular region that then sustain discharge into the second plateau. RESULTS: Across muscles, initial analysis shows increased estimates of PICs at joint angles corresponding to the shortest muscle length of the contracting muscle. For ramp contractions, PICs were estimated with a paired MU analysis approach (ΔF) and found to be 0.385 pps higher (95%CI: [0.174 0.595]) when the agonist muscle was at a relatively shorter length. Likewise, during sombrero contractions, a greater proportion of MUs recruited in the center triangular region sustained discharge into the second plateau at short muscle lengths (TA: 278/538; MG: 378/623; SOL: 24/68) when compared to longer lengths (TA: 114/361; MG: 41/237; SOL: 24/43). CONCLUSIONS: These results suggest that motoneuron excitability is greater at shorter muscle lengths, with MUs exhibiting a greater propensity for sustained discharge. This may be due to an altered composition of inhibitory and/or neuromodulatory input to motoneurons and could inform mechanisms underlying muscle cramps at short muscle lengths.

P1-K-38 Morphological and mechanical properties of the Achilles tendon and their relationship with triceps surae motor unit firing properties during isometric contractions

Ignacio Contreras[1], Michail Arvanitidis[1], Joeri van Helden[1], Deborah Falla[1], Eduardo Martinez-Valdes[1]
[1]*University of Birmingham*

BACKGROUND AND AIM: Achilles tendon morphological and mechanical properties have been extensively investigated in healthy and pathological conditions. However, there is little evidence on the relationship between these properties and the motor unit firing behavior of the triceps surae. This study aims to determine the relationship between morphological and mechanical properties of the Achilles tendon and motor unit firing behavior of the gastrocnemius medialis (GM), gastrocnemius lateralis (GL), and soleus (SOL) muscles during isometric plantarflexion contractions. METHODS: Fifteen healthy individuals (age 30 ± 3.4 years, 11 males, 4 females) were included in the study. B-mode ultrasound images were acquired during a rest condition, and shear wave elastography (SWE) images of the Achilles tendon were obtained (rest and active condition) to indirectly estimate tendon stiffness. High-Density surface EMG of the GM, GL and SOL muscles were recorded using three 64-electrode grids during isometric plantarflexion at 40% of the maximal voluntary contraction. Morphological properties assessed included: Achilles tendon length, thickness, and cross-sectional area (CSA). Mechanical tendon properties comprised passive and active tendon stiffness (shear elastic modulus and shear wave velocity) estimated by SWE. Finally, motor unit firing properties included recruitment threshold (RT), mean discharge rate (MDR), and discharge rate variability (DRV). Additionally, mean torque (MT), torque variability (TV), and maximum torque were assessed. RESULTS: Achilles tendon length was related to GM

DRV (r= -0.581, p= 0.023), and Achilles tendon thickness was related to GM RT (r= -0.566, p= 0.028). Additionally, Achilles tendon length was related to maximum torque r=0.611, p=0.016. Linear regression analysis showed that Achilles tendon length predicts approximately 34% of the variance in GM DRV (Y = 44.83 - 1.34x, C.I. 22.49 - 67.18, p<0.001) and thickness of the Achilles tendon predicts approximately 32% of the variance in GM RT (Y= 59.66 - 80.37x, C.I. 31.09 - 88.22, p<0.001). None of the variables obtained from the SWE was related to any motor unit firing property. CONCLUSIONS: Achilles tendon length and thickness influence GM's motor unit DRV and RT, showing that individual differences in tendon morphology affect motor unit firing behavior. The lack of relationship between the estimated tendon stiffness and the motor unit variables could potentially suggest that 1) tendon stiffness does not influence motor unit firing properties or 2) SWE is not sensitive enough to identify individual differences in tendon stiffness. Further studies comparing different techniques to estimate tendon stiffness are required to test these observations.

P1-K-39 Reliability of measurement for the investigation of serotonergic effects on motor unit discharge characteristics

Benjamin Goodlich[1], Alessandro Del Vecchio[2], Sean Horan[1], Justin Kavanagh[1]
[1]Griffith University, [2]Friedrich-Alexander-University

BACKGROUND: Serotonin (5-HT) is a neuromodulator that binds to somato-dendritic 5-HT2 receptors on motoneurons to regulate the gain of motoneuron activity. However, it is unknown if 5-HT activity is scaled to contraction intensity, where larger muscle contractions may be associated with greater 5-HT effects on motor unit discharge rates. METHODS: Ten healthy participants (25.1 ± 1.9 yr) ingested 8 mg of cyproheptadine, a competitive 5-HT2 antagonist, in a repeated-measures, double-blinded, placebo-controlled experiment. Motor unit activity of tibialis anterior (TA) was assessed with high-density surface electromyographic decomposition during steady-state contractions of 10%, 30%, 50% and 70% of maximal voluntary contraction (MVC). TA activity was assessed at baseline and post-pill ingestion on both the drug day and placebo day (4 assessments in total). Motor units were tracked between pre- and post-pill ingestion using the decomposition filter method, as well as across testing days using waveform cross-correlation. RESULTS: A reliability study indicated that discharge rate of tracked motor units for the placebo condition were highly correlated within testing days (Pearson P <0.01, r^2 = 0.85) and between testing days (Pearson P <0.01, r^2 = 0.80). MVC force did not differ between pre- and post- pill ingestion (p = 0.76) nor between testing days (p = 0.30). Motor unit discharge rate during dorsiflexions did not differ between pre- and post-pill ingestion on placebo testing day (p = 0.08), nor between baseline sessions across testing days (p = 0.25). Motor unit discharge rate was significantly lower post-pill ingestion on cyproheptadine testing day when compared to pre-pill ingestion on the same day (p < 0.01), and post-pill ingestion on placebo testing day (p < 0.01). CONCLUSION: This is the first study to include motor unit tracking via both the decomposition filter and waveform cross-correlation methods with a drug intervention. Overall, these findings demonstrate the critical role that 5-HT has on regulating discharge rate of motoneurons, where 5-HT2 receptor blockade reduced human motor unit discharge rate. These effects were not specific to an individual contraction intensity, which suggests that 5-HT regulates the gain of spinal motoneurons across a full range of forces and may not be scaled to the intensity of muscle contractions being performed.

P1-K-40 Motor Unit Firing Behavior Following Mental Fatigue in Static and Variable-Force Contractions

Michael Marsala[1], Anita Christie[1]
[1]*University of Western Ontario*

AIM: The purpose of this study was to measure how mental fatigue changes motor unit firing behavior and force control in static and variable-force contractions. METHODS: Fourteen participants (7 male, 7 female) between the ages of 18 and 30, each visited the lab on two days, one day for a mentally fatiguing condition using the Psychomotor Vigilance Task (PVT) and one day for a control condition, using a nature documentary. Reaction time during the first and last 5 minutes of the PVT was averaged and compared to establish mental fatigue. On each day, participants performed a series of force-matching tasks twice with their First Dorsal Interosseus (FDI), once before (pre) and once after (post) the 30-minute PVT or nature documentary. The static force matching tasks were performed at 10%, 20%, and 50%, maximal voluntary contraction (MVC) for 5 seconds each. In the variable-force contraction participants traced a sinusoidal wave of .35 Hz frequency, varying 5% around 20% MVC for 20 seconds. The Root Mean Square Error (RMSE) of the force was measured in the middle 3 second window of each static contraction, and a window of one full period of the sinusoidal wave. Using surface decomposition electromyography, motor unit firing rates (MUFR) and coefficient of variation of the inter-spike intervals (CVISI) were determined in the same time window RMSE was measured. RESULTS: Reaction time in the PVT was significantly higher in the last 5 minutes compared to the first 5 minutes of the task ($p=0.008$), indicating mental fatigue. In the 20% ($p=0.01$) and 50% ($p=0.01$) MVC contractions, RMSE of force decreased from pre to post, but did not change differently across days ($p\geq0.4$). There were no significant differences in RMSE at 10% MVC ($p\geq0.1$) or during the variable-force contraction ($p\geq0.3$). Mean MUFR at 50% MVC decreased from pre to post ($p<0.001$) but did not change differently across days ($p=0.1$) and was not significantly different during any other contractions ($p\geq0.2$). Overall, at 20% MVC the CVISI was significantly greater on the documentary day, compared with the PVT day ($p=0.02$). In the variable-force contraction, CVISI was lower post-PVT, compared to pre-PVT ($p=0.05$), with no difference across time on the documentary day ($p=0.3$). CONCLUSIONS: Force control and MUFR were unaffected by mental fatigue during both static and variable-force contractions. Mental fatigue seems to influence motor unit firing behavior by reducing the CVISI in variable force, but not static contractions in the FDI.

P1-K-41 Mean Power Frequency of Boys and Men During Discrete, Progressive, Isometric Contractions Carried to Exhaustion

Jordan Langille[1], Stacey Woods[1], Raffy Dotan[1], Craig Tokuno[1], David Gabriel[1], Bareket Falk[1]
[1]*Brock University*

BACKGROUND AND AIM: Numerous physiological and performance-related child-adult differences have been observed, persisting even when body- and muscle-size differences are accounted for. One suggested explanation is that children do not utilize their higher-threshold (presumably, type-II) motor units (MU) to the same extent as adults. As type-I and type-II fibres differ in their conduction velocity and firing frequencies, the mean power frequency (MPF) of the electromyographic signal (EMG), may reflect differential MU recruitment. The purpose of this study is to examine potential MPF-pattern differences between children and adults during discrete, progressive, isometric knee-extensions. METHODS: Secondary analysis was performed on data of 17 boys and 20 men who completed a progressive isometric contraction protocol to exhaustion, consisting of 5-s isometric contractions, starting at 25% 1RM, and increasing by 3% every 5 contractions (Woods et al. 2019). EMG was recorded from the vastus lateralis. Independent t-tests were used to assess group differences in anthropometric variables, mean MPF (MPFmn), peak MPF (MPFPK), torque at MPFPK (%1RM), and MPF range. An interpolation polynomial was applied to each participant's mean stage MPF trend to account for the variance in the number of completed stages. Repeated measures ANOVA was then used to assess group differences in the various MPF patterns. In view of the boys' lower adiposity than the men's (10.1±7.5 vs. 17.1±5.6%), % body fat was used as a covariate. RESULTS: Boys reached a higher relative load at exhaustion compared with men (80.4±6.9 vs. 71.5±10.0 %1RM). MPFmn (109.7±17.6 vs 118.2±20.3 Hz) and MPFPK (113.8±17.9 vs. 124.1±22.0 Hz) were significantly higher in men. There was a significant group effect ($p<0.001$) in the MPF response, reflecting higher MPF in men throughout the protocol. MPF gradually increased and then decreased towards the end of exercise (stage effect, $p=0.006$), with large variability. The group-by-MPF interaction did not reach significance ($p=0.19$). 65% of the participants displayed the expected inverted-U MPF pattern. Within this subset, the torque at which MPFPK occurred was significantly higher in the boys compared with the men (60.4±20.6 vs. 46.7±10.7 %1RM). CONCLUSIONS: The boys' higher relative intensity at which MPFPK occurred, as well as their higher relative torque at exhaustion, suggest lower type-II muscle-fibre composition or lower type-II motor-unit activation in children. Overall, the results are in line with previous findings, suggesting lesser higher-threshold MU utilization in children. The underlying reasons for the variability in the observed MPF pattern and the potential confounding effects of contraction intensity and fatigue on child-adult differences, should be examined by future research.

L - Muscle Synergy

P1-L-42 Investigation of muscle synergy asymmetry during walking in individuals with cerebral palsy

Yosra Cherni[1], Nicolas Turpin[2], Simon Laurendeau[3], Maxime Robert[3], Katia Turcot[3]
[1]Université Laval / cirris, [2]Université de la réunion, [3]University Laval/Cirris

Introduction: In individuals with cerebral palsy (CP), muscle coordination is severely affected during functional tasks. It is also recognized that a reduced number of muscle synergies are present during walking when compared to typically developed individuals, indicating a lower motor complexity. However, it is still not clear whether these abnormal synergies are fundamentally abnormal (e.g., abnormal axonal sprouting) and if they are stable/symmetric between the two legs during walking. Objective: The aim of this study is to investigate to investigate muscle synergies symmetry in both legs of individuals with CP. Methods: Eight individuals with CP were included in this study. All participants walked barefoot (no orthosis) with their usual aids, if required (e.g., walker, canes) along a 10-meter walkway in the gait laboratory at their comfortable speed. Six electromyographic (EMG) electrodes were placed on each leg of the participants to record the activity of following muscles: (1) Rectus Femoris (RF), (2) Vastus Lateralis (VL), (3) Semitendinosus (ST), (4) Gastrocnemius Medialis (GM), (5) Soleus (SOL), and (6) Tibialis Anterior (TA). EMGs were processed to the following sequence: Notch filter (50 Hz), high pass filtering (30 Hz), full-wave rectification, and low pass filter with a fourth order Butterworth filter (10 Hz). Each EMG envelope was normalized with respect to the overall mean value. A synergy analysis was conducted to assess the temporal and spatial structure of the muscles coordination, using non-negative matrix factorization (NNMF). NNMF iteratively factorizes the EMG matrix E into the synergy activation matrix H and the synergy weighting matrix W ($E=W\times H$). Synergy vectors were normalized by their norm. The reconstruction quality was assessed by means of the Variation Accounted For (VAF). The number of synergies was defined as the minimal value for which the lower bound of 95%-confidence interval of the total VAF was greater than 90%. A cross-validation procedure was used to compare the synergies across time and legs. Differences in EMG activation profiles between both legs were tested using t-test based on the Statistical non-Parametric Mapping toolbox (significant threshold=0.05). Preliminary results: Two to three synergies were required to reconstruct the EMG envelopes during walking. Our results showed robust synergies across time in individuals with CP. On average, the participants presented symmetrical synergies with a tendency to asymmetry (in 4 participants out of 8). In terms of muscle activation profiles, our results showed significant difference in TA ($p \leq 0.001$, change ranged from 8 to 64% of gait cycle) and VL ($p \leq 0.01$, change ranged from 24 to29% and 88 to 92% of gait cycle). No differences between the two legs were observed in other tested muscles. Conclusion: The tendency of asymmetry in synergies is likely due to the lateralization process which lead to the presence of a dominant leg or a most affected leg in individuals with CP. Our preliminary results should be interpreted in relation to biomechanical gait parameters and confirmed in a larger sample size.

P1-L-44 Shoulder muscle activation synergy changes with load, arm rotation, and plane of arm elevation

Spencer Nehls[1], James Michaud[1], Traci Bush[1], Vassilios Vardaxis[1]
[1]*Des Moines University*

BACKGROUND AND AIM: The complexity of movement control at the shoulder can be represented by muscle synergies as they characterize the organization of muscles into functional groups by the central nervous system, aiming to reduce coordinative structures. It has been demonstrated that pathology disrupts conventional muscle synergies and contributes to disease states. Thus, muscle synergies provide a framework for rehabilitation. In this study, we aim to identify how load, arm orientation, and plane of arm elevation impact muscle synergies around the shoulder joint. METHODS: Twenty male adults (age 26.0±2.8 yrs.) with no history of shoulder pathology performed arm elevations to 120° and back, with their right dominant arm, on the coronal, scapular, and sagittal planes under 4 weight (0,1,3, & 5 lbs.) and 2 arm rotation (full-can & empty-can) conditions. Surface electromyography (sEMG) data was recorded (1200Hz by a 16-bit A/D) on 10 muscles: anterior, middle and posterior deltoid, clavicular and sternal parts of the pectoralis major, upper, lower, and middle trapezius, serratus anterior, and short head of biceps brachii. Motion capture was used to track the arm elevation (at 120Hz) and to identify the beginning and end of each trial. Activation patterns were demeaned, band-pass filtered (10-450 Hz), and RMS processed using MATLAB. Five trails per condition were ensemble-averaged. The RMS data was normalized to peak sEMG value across all conditions for each muscle. Non-negative matrix factorization (NNMF) was used for synergy identification and structure comparisons.
RESULTS/DISCUSSION: Two synergies were required to represent the individual muscle activation patterns across all conditions for all participants, determined on the criterion of the minimum number of synergies that summed to at least 90% variance accounted for (VAF) with a minimum single synergy contribution of 3% VAF. The overall mean VAF was 94.2 ± 1.6% across participants and conditions. An "antigravity/plane of elevation" synergy was identified composed of the middle deltoid, upper trapezius, and serratus anterior muscles for all 3 planes of arm elevation. Plane specific muscles were added to this synergy specifically, the anterior deltoid for the sagittal plane, the anterior deltoid and middle trapezius for the scapular, and the lower trapezius for the frontal plane. A "scapula position/control" synergy was also found, comprised of the upper trapezius and the lower pectoralis major in all planes. The upper pectoralis major and the middle trapezius were added to this synergy for the sagittal and frontal planes, respectively. Load altered the second synergy for the sagittal plane only, by recruitment of the biceps short head. Empty-can arm rotation changed the composition of the first synergy by including the

posterior deltoid for all planes and weight conditions. CONCLUSIONS: The 2 muscle synergies identified, described the coordination of the overall shoulder (glenohumeral/scapulothoracic) motion, for arm elevations varied by plane, load, and rotation. Our findings can be used in the development of targeted evidence-based rehabilitation protocols.

M - Neuromechanics

P1-M-45 Estimation of dynamically consistent joint stiffness during joint rotations via EMG-driven musculoskeletal modelling

Christopher Pablo Cop[1], Alfred C. Schouten[2], Bart F.J.M. Koopman[1], Massimo Sartori[1]
[1]University of Twente, [2]Delft University of Technology

BACKGROUND AND AIM: Human movement emerges from the coordinated interplay between neural and musculoskeletal (MS) structures, in interaction with the environment. Despite extensive knowledge on anatomy and function of neural and MS structures, there is a knowledge gap in the cause-effect relationships between the neural and the biomechanical levels of movement. Joint stiffness is a crucial neuromechanical property that enables stable interaction with the environment and adaptation across different kinds of terrain. Due to the causal inference with the environment, joint stiffness cannot be obtained from recorded motion and torques during normal movement. Perturbations with system identification (sys. id.) techniques are required to estimate joint stiffness. Different techniques exist to estimate and predict joint stiffness, ranging from data-based methods, e.g. sys. id. methods, to model-based methods, e.g. MS models. Using a combination of both methods can help us understand the causal relationships between the mechanical and the neural aspects of human movement control. In this work we show predictions and validations of human joint torques and stiffness simultaneously using MS models driven by high-density electromyograms (HD-EMGs). METHODS: A healthy adult was instructed to follow a sinusoidal angle trajectory (amplitude: 0.15 rad, frequency: 0.6 Hz) by plantar- and dorsiflexing the right ankle using a dynamometer. Ankle angle and torque were measured while small and fast position perturbations (amplitude: 0.03 rad, switching time: 0.15 s) were applied. HD-EMGs of the tibialis anterior and soleus muscles, and bipolar EMGs of the gastrocnemii and peroneus longus muscles were acquired. The perturbations were used to estimate reference joint stiffness values using a multi-segment time-varying sys. id. method. A calibrated HD-EMG-driven MS model was used to predict joint torque and joint stiffness. Reference and predicted torque and stiffness were compared using the root mean squared error (RMSE) and the coefficient of determination (R^2). RESULTS: Our model was able to track measured torque profiles (RMSE = 1.8 ± 0.3 Nm; R^2 = 0.95 ± 0.02) and reference joint stiffness estimates (RMSE = 4 ± 1 Nm/rad; R^2 = 0.6 ± 0.2). Results expressed as mean ± standard deviation. CONCLUSIONS: For the first time we have a computational framework that allows the calibration of model parameters by minimizing the difference between reference and predicted joint torques and joint stiffness simultaneously. This could lead to model parameters that better represent neuromechanical behaviour across a wide repertoire of tasks and help identify differences in joint stiffness control across healthy and pathological populations. Moreover, being able to decode joint stiffness and joint torques, from HD-EMGs and joint kinematics might enable biomimetic and robust controllers for assistive robotic technologies that outperform current devices that are only position- or torque-controlled.

P1-M-46 Behavioral exploration of musculoskeletal systems integrating spinal regulations for natural and artificial controls

Daniel Cattaert[1], Matthieu Guémann[2], Bryce Chung[3], Pierre-Yves Oudeyer[4], Aymar de Rugy[5]

[1]INCIA, UMR5287, CNRS et Université de Bordeaux, [2]IRBA, unit PEACE, dept ENOP, [3]Emory University, [4]INRIA Bordeaus Sud-Ouest, [5]Univ. Bordeaux, CNRS, EPHE, INCIA, UMR 5287

BACKGROUND AND AIM: Neuro-mechanical models are essential to increase our understanding of the fundamental mechanisms underlying natural sensorimotor control, and to foster robotic designs using them. Yet, the complexity of those models is such that current optimization methods are unsuited to establish the range of useful behaviors they could produce along with their associated parameters. Our goal is to provide both, using a Goal Exploration Process (GEP) algorithmic process, which is a model discovery mechanism leveraging behavioral diversity search issued from recent advances in developmental machine learning. METHODS: In order to present the GEP process, we designed simplified neuro-mechanical models that are nevertheless too complex to allow a direct exploration of all parameter combinations. Models consists of a single (elbow) joint actuated by two muscles and their associated spindles, alpha and gamma motoneurons receiving simple (non-dynamic) step commands. The GEP builds a repertoire of valid actions through iterative sampling of target behaviors combined with stochastic variation on the parameter settings that elicited their closest neighbor behaviors in this repertoire. Starting with at least one valid behavior (seed), other diverse valid behaviors are progressively added to the repertoire. RESULTS: GEP was found to widely outperform optimization methods in terms of its ability to rapidly establish a repertoire of valid actions, and to find a large range of behaviors not found otherwise. Several applications of this GEP platform are presented that allow a direct comparison of the behavior repertoires obtained with models differing in sensory or motor properties, the target cell receiving descending commands, the complexity of the sensorimotor circuits etc. Moreover, GEP demonstrates the redundancy of the parameter space: the same behavior can be produced with a variety of parameter sets. This redundancy may be important for the robustness of the system, or for choosing the best strategy facing perturbing environment. CONCLUSIONS: The GEP process presented here allows fast and reliable discovery of the behavior repertoire associated with a given neuro-mechanical model based on low-level sensorimotor loops. Comparison of behavioral space obtained after selective manipulation of various elements of neuro-mechanical models should also help understand natural control, and promote its emulation in bio-inspired robotics.

P1-M-47 Facilitation of the abductor hallucis Hoffman reflex when walking in textured foot orthoses

Kelly Robb[1], Lara Green[1], Stephen Perry[1]
[1]Wilfrid Laurier University

BACKGROUND AND AIM: There remains minimal evidence investigating the effects of foot orthoses on foot intrinsics muscles and/or on neurophysiological measures such as the Hoffmann reflex (H-reflex). Despite this scarcity of research, texture added between the foot sole and walking environment has recently gained attention as a method of facilitating cutaneous afferents to intentionally modulate lower limb [1] and foot intrinsics muscle activity [2]. The purpose of this study was to measure motorneuron excitability changes (as measured by the abductor hallucis H-reflex) when wearing a textured foot orthotic during locomotion. METHODS: The abductor hallucis H-reflex and M wave responses were elicited in twenty-one healthy young adults (23.7±5.2 years) completing 40 block-randomized level walking trials. A custom-made platform modified two steps in the walking environment to alternate between hard (plywood) and soft (foam) walking conditions. Participants wore two different foot orthoses: 1) non-textured FOs (FO) (Thin Sport, Sole), 2) textured FOs (FOT) (a textured top cover was added to the non-textured FOs). Kinematic data were measured with a

standardized 12-IRED marker setup and two Optotrak Certus cameras (SF=100Hz). Surface EMG (SF=2000Hz) and H-reflex data were measured with a wireless EMG system (Noraxon Ultium) and Digitimer constant current stimulator (DS7A Digitimer). In non-weightbearing, brief (<1ms) electrical stimulations were gradually increased by 0.5 mA increments until the M-wave maximum amplitudes were determined. During each walking trial, posterior nerve stimulation (H-reflex expressed as 18-20% of the peak-to-peak M-wave) was timed off the force plates and limited to the initial contact phase of stance. RESULTS: Preliminary results of this study demonstrate a significant main effect of foot orthotic condition ($F_{1,20}=51.10$, $p<.001$). Walking in FOTs significantly increased the abductor hallucis H/M ratio when walking on both the hard (FO: 0.12mV±0.07; FOT: 0.15mV±0.1) and soft (FO: 0.11mV±0.06; FOT: 0.14mV±0.09) flooring surfaces (Figure 1). Future data analysis will extrapolate the angular position of the anterior-posterior and vertical IRED marker coordinates to calculate sagittal plane hip, knee, and ankle kinematics. CONCLUSIONS: This study provides evidence to support the use of textured foot orthoses as a method of indirectly increasing spinal reflex excitability, as measured by the abductor hallucis H-reflex during level walking. These results strengthen research in support of foot orthoses functioning through a neuromotor paradigm via the modulation of foot sole cutaneous afferents and their effect on lower extremity motorneuron pools. REFERENCES: [1] Ritchie C et al. (2011). Gait and Posture, 33: 576-581. [2] Robb KA et al. (2021). In preparation, Gait and Posture.

P1-M-48 An Investigation of the Role of Plantar-Surface Cutaneous Sensation on Dynamic Balance Control During Slip Perturbations

Keara Sutherland[1], Rachel Billo[1], Jessica Berrigan[1], Stephen Perry[1]
[1]*Wilfrid Laurier University*

INTRODUCTION: Slips perturbations during gait have been identified as a major factor contributing to falls due to their truly unexpected characteristics. A slip and the related decrease in friction can potentially be detected via plantar cutaneous mechanoreceptors found on the foot sole. Sensory information during perturbed stance (Perry et al. 2000; Meyer et al. 2004) and gait termination (Perry et al. 2001) provides information on the limits of the base of support, centre of mass relationship via pressure changes, assisting in the maintenance of balance control. Currently, there are studies that have examined the biomechanics of slip perturbations, but no studies to date have examined the role of sensory information when exposed to a slip perturbation. The aim of this study was to determine the importance of cutaneous plantar surface sensation in detecting and reacting to a slip perturbation by reducing foot sole sensation via hypothermia. The evaluation of slip severity and muscle activation timing and magnitude will be done to determine if plantar surface sensation plays a role in the reaction to an unexpected slip perturbation. METHODS: Twenty young adult participants (control (n=10, 8 females) and experimental (n=10, 7 females)) were recruited. Participants in the experimental group submersed their foot soles in ice water for 15 minutes prior to performing the slip/walking trials. Both groups completed the same experimental protocol. High friction sandpaper placed at each foot contact was secured along the walkway during non-slip trials. Waxed paper adhered to the underside of a sandpaper sheet was exchanged on the second force plate to elicit an unexpected heel contact slip perturbation. Unexpected slips were presented after a predetermined number of normal walking trials. Muscle activity was collected from eight lower limb muscles using surface electromyography. Kinematic data was used to determine slip severity and distance. Force plate data was used to record initial contact during the slip (muscle onset was measured relative to this time). A one-way ANOVA was used to assess group effects (control, experimental) of slip severity, slip distance, muscle timing, and magnitude. RESULTS: Slip distance (0.2m vs. 0.3m, $p<0.05$) and slip severity occurrences (3 vs. 6) were increased when sensation was reduced. Muscle activation onset was reduced in the medial hamstring (145 ms vs. 87 ms, $p<0.01$) and peroneus longus (132 ms vs. 106 ms, $p<0.05$) due to reduced sensation. Modulation of normalized muscle activity magnitude occurred as an increase in the medial hamstring activity (2.8% vs 1.5%, $p<0.05$) due to reduced sensation. All muscle results were evaluated in the leading (slipped) limb. CONCLUSIONS: Although slip severity and slip distance was increased due to reduced sensation, muscle timing and activity from the leading limb did not show delayed or reduced values. Investigation of the trailing limb muscle activity may provide further insight.

O - Pain

P1-O-49 The precision of people with chronic low back pain in locating nociceptive stimuli on a body chart

Marco Barbero[1], Deborah Falla[2], Matteo Agnelotti[3], Davide Trenta[3], Alberto Gallace[4], Corrado Cescon[1], Davide Corbetta[3]

[1]University of Applied Sciences and Arts of Southern Switzerland, [2]University of Birmingham, [3]Vita-Salute San Raffaele University, [4]University of Milano-Bicocca

BACKGROUND AND AIM: Pain drawings are frequently used to assess the somatic distribution of pain. Previous studies have confirmed that people with chronic pain can reliably report both the extent and location of their painful symptoms. However, the conscious sense of body and proprioception can be impaired in people with chronic pain, potentially affecting the validity of their pain drawings. Investigations that assess the precision of people with chronic pain in locating painful symptoms on body charts (BC) are needed. This study aimed to evaluate how precisely people with chronic low back pain (CLBP) can indicate the location of nociceptive stimuli applied over their back on a BC compared to asymptomatic people. Moreover, the precision in locating nociceptive stimuli was assessed in relation to the clinical features of CLBP. METHODS: Thirty-one people with CLBP and 36 healthy volunteers participated. A grid of 4 rows and 5 columns was drawn over the participants' lumbar region. Six circular electrodes connected to an electrical stimulator were applied at points on the grid: one on the cross between column three and row four and five in the remaining crosses by means of a stratified randomization procedure. Additionally, six electrodes disconnected from the electrical stimulator were distributed over the remaining crosses. Eight painful electrocutaneous stimuli were randomly delivered to each connected electrode. After each stimulation, participants were asked to indicate on a BC, presented on a tablet, where they perceived the stimulus. Then, the BC was centred on a canvas 768x1024 pixel (px), and the identified locations of painful stimuli were defined by X and Y coordinates. For each stimulated electrode the barycentre was computed for the eight locations reported on the BC. The precision in reporting the location of 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 (DD-m). The precision in locating the nociceptive stimuli was compared between the two groups using Mann-Whitney U test. Spearman's correlation coefficients were used to assess whether the precision in locating the nociceptive stimuli was related to the clinical features of CLBP including perceived pain, disability, kinesiophobia and central sensitization. RESULTS: In participants with CLBP, the mean(sd) X-sd was 11.2(5.6) px, the mean(sd) Y-sd was 20.9(9.7) px and the mean(sd) DD-m was 20.7(9.3) px. In healthy volunteers, the mean(sd) X-sd was 10.5(3.8) px, the mean(sd) Y-sd was 20.5(6.2) px and the mean(sd) DD-m was 18.5(6.3) px. No significant group difference was found in reporting the painful stimuli. In people with CLBP, DD-m showed a significant moderate

correlation with central sensitization (r=0.54, p=0.01). CONCLUSION: People with CLBP and healthy people showed the same precision in reporting the painful stimuli on a BC. Overall, the precision in locating the delivered nociceptive stimulations was 2-5 mm. In people with CLBP, the precision in locating the painful stimuli can be impaired by central sensitization.

P1-O-50 Adaptation of scapular kinematics and trapezius's muscle activity to movement-evoked shoulder pain

Giacomo Nardese[1], Deborah Falla[1], Valter Devecchi[1], Alessio Gallina[1]
[1]University of Birmingham

BACKGROUND AND AIMS: Previous research has shown that tonic experimental pain changes the activation of periscapular muscles [1]. However, tonic pain may not be the most appropriate experimental model of pain [2] since people with clinical shoulder pain conditions usually report an increase in pain during movement. In this study, we investigated whether pain associated to shoulder movement induces motor adaptation of the muscles acting on the scapula. METHODS: 15 healthy participants performed 12 sets of a box-lifting task between 2 shelves positioned at the hip and eye level. Two minutes of rest were provided between sets and the weight of the box was 1 kg. In sets 3-12, the pain was induced over the posterior acromion using sinusoidal electrical stimulation at 4 Hz [3], modulated to induce a pain intensity of 4/10 when the activity of the anterior deltoid was equal to or higher than the peak measured at baseline, and of 1/10 when lower than 80%. Participants reported their perceived pain intensity after each set of 10 repetitions. For each set, we recorded scapular elevation using an inertial motion unit system and muscle activity from the Upper (UT), Middle (MT) and Lower (LT) divisions of the Trapezius. Electromyographic (EMG) signals were band-filtered at 30-350 Hz to remove stimulation artefacts and the frequency spectra were visually inspected to ensure the absence of harmonics; envelopes were calculated by low-pass filtering the rectified EMG at 10 Hz. We extracted peak muscle activation and scapular elevation during the lifting phase and used separate Friedman tests to compare each variable at baseline (sets 1,2), early (sets 3,4) and late adaptation (sets 11,12). Scapular elevation and muscle activity are reported as percentage change from baseline. RESULTS: Perceived pain did not change between Early (median [25th, 75th percentile]: 2.5 [1.3, 3.0]) and Late (2.5 [1.9, 3.2]) phases of the task. Friedman test identified significant changes in scapular elevation (p=0.002) and muscle activation (p≤0.017, Figure). Post-hoc test revealed that early adaptation was characterised by less scapular elevation (-14.0% [-33.0, -5.9], p=0,002) and decreased activation of UT (-20.4% [-27.7, -10.1], p=0.006) and MT (-9.5% [-23.6, -6.4], p=0.032). In the late adaptation phase, less scapular elevation (-20.3% [-25.1, -6.5], p=0.032) was observed together with an increased LT activation (24.7% [10.9, 49.1], p=0.006). CONCLUSIONS: Our findings suggest that movement-evoked pain could be a useful experimental pain model to examine neuromuscular and biomechanical adaptations to shoulder pain. Movement-evoked shoulder pain results in reduced scapular elevation, and different muscle strategies may be responsible for these changes in scapular kinematics in the early and late adaptation phase. REFERENCES: [1] Diederichsen, L.P. et al. Exp Brain Res 2009; 194(3):329-337 [2] Ford, B. et al. Scandinavian Journal of Pain 2019;20(1):167-174 [3] Gallina. A. et al. J Physiol 2021;599(9):2401-2417

P1-O-51 Degenerative diseases of the intervertebral discs: an approach to electromyographic activity of masticatory muscles

Marcelo Palinkas[1], Flávia Cecilio[1], Nicole Bettiol[1], Claire Gauch[1], Lilian Andrade[1], Isabela Regalo[1], Ligia

Gonçalves[1], Selma Siéssere[1], Simone Regalo[1]
[1]School of Dentistry of Ribeirão Preto, University of São Paulo, Ribeirão Preto

BACKGROUND AND AIM: The functions of the human body must be in harmony so that the systems and organs remain balanced. However, pathological and/or behavioral changes of various intensities can interfere in this equilibrium, leading to functional changes. The objective of this study was to determine the electromyographic activity of the masseter and temporalis muscles of individuals with and without intervertebral disc degeneration. METHODS: Twelve adult individuals without temporomandibular disorder and normal occlusion were divided into two groups: case (n = 6; mean age 37.1 ± 1.3 years; mean body mass index 27.09 ± 1.81 kg / m2) and control (n = 6; mean age 37.0 ± 2.4 years; mean body mass index 25.92 ± 1.99 kg / m2). The electromyographic signals of the masticatory muscles during mandibular rest, right and left laterality, protrusion and dental clenching in maximum voluntary contraction were recorded using a wireless system (Trigno, Delsys Inc., Boston, MA, USA). The 95% significance level was used (Student's t test, p <0.05). This study was approved by the Research Ethics Committee (process No 29014620.1.0000.5419). RESULTS: There was no significant difference between the groups for age (p = 0.95) and body mass index (p = 0.67). There was significant difference between groups for the right masseter muscle at rest (p = 0.05), with lower electromyographic activity for the case group. CONCLUSIONS: These results suggest that adult individuals with degenerative diseases of the intervertebral discs have functional changes in the electromyographic activity of the masseter and temporalis muscles. ACKNOWLEDGEMENT: FAPESP and National Institute and Technology - Translational Medicine (INCT.TM).

P - Rehabilitation

P1-P-52 Association between gait and walking lower limb force control in stroke patients

Yan-Ting Chen[1], Li-Yu Lin[2], Hui-Yu Tseng[2], Chih-Hung Chen[1], Pei-Yun Lee[1], Sang-I Lin[1]
[1]College of Medicine, National Cheng Kung University, [2]Tainan Hospital, Ministry of Health and Welfare

BACKGROUND AND AIM:The control of the lower limb force used for body weight support (BWS) and forward propulsion (FP) is critical for walking but often limited after stroke. The purpose of this study was to determine the association between such force control and gait in chronic stroke patients. METHODS:Ten community ambulatory adults with unilateral stroke for more than 6 months underwent self-paced walking on the GAITRite pressure-sensor mat to measure stride characteristics. They also walked on an 8-meter walkway with two imbedded force platforms to measure the upward vertical ground reaction force (GRF) to indicate the BWS force, and positive anterior GRF to indicate the FP force. The lower limb muscle strength was measured using handheld dynamometer. RESULTS:The affected side BWS or FP force (r=.061 ~ .436, p=.208~.931) and the non-affected side BWS force were not significantly correlated with any stride characteristics (r=0.12~.577, p=0.44~0.975). The non-affected side FP force was significantly correlated with the affected side step length (r=-.777, p=.008), single limb support time (r=-.751, p=.012), and stride time (r=. 839, p=.002). The lower limb muscle strength was not correlated with any stride characteristic (r=.065~.591, p=.072~.834). CONCLUSIONS:This study found that the affected limb stride characteristics were highly correlated with the unaffected limb FP force but not the affected limb muscle strength. This important compensatory behavior suggested that for chronic stroke patients whose motor recovery of the affected limb may be limited, strength and endurance training of the non-affected plantarflexors may be beneficial for improving walking performance.

P1-P-53 Operant Conditioning of Extensor Carpi Radialis Motor Evoked Potential after Neurological Injury

Blair Dellenbach[1], Jinsook Roh[2], Alan Phipps[1], Aiko Thompson[1]
[1]Medical University of South Carolina, [2]University of Houston

BACKGROUND AND AIM: The corticospinal pathway and its plasticity are essential in sensorimotor function recovery after neurological injuries. Thus, an intervention that can increase the excitability and plasticity of the corticospinal pathway may enhance sensorimotor rehabilitation. Operant up-conditioning of the motor evoked potential (MEP) to increase corticospinal excitability may therefore, improve corticospinal activation of the targeted muscle and improve functions in which that muscle participates. This case series of 3 individuals with weak wrist extension following neurological injury examined whether operant up-conditioning of the motor evoked potential (MEP) can increase the wrist extensor Extensor Carpi Radialis (ECR) activity and improve upper extremity function in individuals with chronic neurological injury. METHODS: The participants were a 56-year-old female 2.5 years post subcortical ischemic stroke; a 51-year-old female 7 years post cortical and subcortical ischemic stroke; and a 39-year-old male 1.5 years post C4-C7 spinal cord injury. The participants were exposed to 6 baseline and 24 MEP up-conditioning sessions (3 sessions/wk over 10 wks). In all sessions, ECR MEPs were elicited at 10% above motor threshold while the participant maintained a pre-set absolute amplitude of background EMG activity (equivalent to ~30% baseline maximum voluntary contraction (MVC) level as measured by EMG). In all 225 MEP trials of baseline sessions and the first 20 trials of each conditioning session, the participant received no feedback as to MEP size (i.e., control MEPs). Then, in 225 conditioning trials of each conditioning session, the participant was asked to increase MEP size, and received immediate feedback as to whether MEP was larger than a criterion (i.e., whether the trial was a success). MVC was measured at the beginning of each session. Fugl-Meyer Upper Extremity Assessment (FMA-UE), Action Research Arm Test (ARAT), and Box and Block Test (BBT) were administered at baseline, after 12 conditioning sessions, after 24 conditioning sessions (post-training) in all participants. RESULTS: Each participant demonstrated improvements in at least one outcomes measure. The 56-year-old female with stroke demonstrated a 91% increase in MVC, 8-point increase in FMA-UE score, an increase from 11 to 17 boxes on the BBT, and no change in ARAT. The 51-year-old female demonstrated a 36% increase in MVC, 8-point increase in ARAT, and no change in FMA-UE. The 39-year-old with SCI demonstrated a 328% increase in MVC, an increase from 1 to 7 blocks on BBT, and no change in ARAT or FMA-UE scores. DISCUSSION: The results support our hypothesis that operant conditioning of ECR MEP can increase voluntary activation of wrist extensors and improve upper extremity function in individuals after neurological injury. We plan to enroll additional participants to continue to explore the effects of MEP operant conditioning on wrist extensor activity and upper extremity function in individuals post neurological injury.

P1-P-54 The relationship between soleus and gastrocnemius muscles length and static and dynamic balance control.

Marcio dos Santos[1], Hermes Romero[1], Tatiana Bobbio[1], Scott Sullivan[1]
[1]University of St Augustine for Health Sciences

Balance impairments are common manifestations after ankle and knee injuries in young adults, athletes, and non-athletes. The Balance Error Scoring System (BESS) and the Lower Quarter Y-Balance Test (YBT) are common clinical tools to assess static and dynamic balance, respectively, in these individuals. Calf muscles length may be affected by activity and injury, and these muscles play an essential role in providing mechanical constraints and somatosensorial feedback to maintain and regulate standing posture. Would calf muscles length impact the results of these dynamic and static balance control tests? The study included 47 healthy young participants (28 females/19 males; age: 25±3 years; height: 168 ±9 cm; weight: 70±20 Kg) without any lower limb injuries. We used a goniometer to measure the soleus and gastrocnemius length through ankle dorsiflexion range of motion with knee extended (gastrocnemius) and flexed (soleus). We measured the static balance control via the BESS test. The participants performed the test once, and we used the total number of errors of the 6 conditions for the analysis. Second, we assessed the dynamic balance control via YBT; the participants performed 3 trials in each direction (anterior, posterior right, posterior left) bilaterally. We normalized the YBT measures by the participant's leg length and used the mean of three trials for the statistical analysis. We used Person's correlation between the soleus and gastrocnemius length and the YBT and BESS test scores. Linear regression was applied to the significant relationships (IBM SPSS Statistics). The BESS and YBT composite average scores were 13±7 errors and 75 cm, respectively. The average measures of soleus and gastrocnemius length were 17 and 7 degrees, respectively. Results showed a statistically significant positive and moderate linear relationship between gastrocnemius length and BESS test score ($r=.45$, $p < .005$). The R square was 0.202, which implies that the Gastrocnemius length explains 18.4% of the Bess test. The results showed that with every increase of one degree in ankle dorsiflexion angle (Gastrocnemius length), the Bess test score (on average) increases by 0.57 (95% CI 0.229 to 0.911) errors ($p < .005$). The soleus length was not correlated with the BESS test measures. We did not find significant correlations between the soleus and gastrocnemius lengths and the YBT measures. Healthy participants with limited ankle dorsiflexion caused by shortened gastrocnemius demonstrated better scores (fewer errors) in the BESS test. BESS is a static test and requires controlling balance mostly around the ankle joints. Likely, more constraint at the ankle joint may decrease the variations of the center of mass, providing better postural stability to the subjects. In contrast, the dynamic YBT does not depend only on the ankle joint but also on the chain of joints (ankle, knee, hip, and spine). Therefore, any other joint of this chain could compensate for any change in the length of ankle muscles (soleus and gastrocnemius). In conclusion, the gastrocnemius muscle length is a new potential factor to consider when assessing static balance control.

P1-P-55 Strength and HDEMG Features of the Quadriceps During Slow, Moderate and Fast Isokinetic Knee Extensions in Men and Women

Usha Kuruganti[1], Jacqueline Toner[2], Brayan Daniel Caldera Rosas[3]
[1]University of New Brunswick, [2]Dalhousie University, [3]Universidad de Guadalajara

BACKGROUND AND AIM: Healthy quadriceps muscles are critical for successful lower limb movement such as walking, running and activities of daily living. Impairment to any of the four quadriceps can impact an individual's mobility. While the anatomical differences between males and females are well understood, the differences in quadriceps neuromuscular control patterns remains relatively understudied. Previous studies examining the quadriceps using multichannel electromyography (EMG) have found contradictory results due to sex, however, were limited in the number of muscles studied as well as speed of contraction. Better understanding of sex differences may provide greater understanding of movement related impairment. The purpose of this study was to compare spatial HDEMG distribution patterns of three quadriceps muscle between healthy females and males during isokinetic knee extensions of varying speed. METHODS: Nineteen participants, male (n=9) and female (n=10) (mean age = 22.27 ± 2.4 years) completed randomized maximal isokinetic knee extensions at 4

speeds (30, 60, 90 and 120�/sec) with 5 minutes of rest in between to avoid fatigue. Multichannel EMG data were recorded during contractions at 1024 Hz (Sessantaquattro, OT Bioelettronica, Italy, input impedance: >90 MΩ, CMMR: >96 dB, filter: 10 Hz low cut-off, 500Hz high cut-off, noise: <2�VRMS). Three semi-disposable grids were placed over the vastus lateralis (VL), vastus medialis (VM) and the rectus femoris (RF). A 64-channel electrode grid (ELSCH064NM2, OT Bioelettronica, Italy) comprised of 13 rows and 5 columns of electrodes was placed over the RF while two grids, each consisting of 32 electrodes comprised of 8 rows and 4 columns of electrodes (LISiN-OT Bioelettronica, Torino, Italy, model ELSCH4x8NM6) were placed over the VL and the VM. A repeated measures ANOVA was used for statistical analysis (alpha level = 0.05). RESULTS Females produced less torque across all speeds compared to males (p<0.001). There was a significant difference detected in differential intensity with males producing significantly greater differential Intensity values than females (p<0.001). Males had significantly greater mean RMS values (VL:0.14 ± 0.14; VM: 0.16 ± 0.14) than females (VL: 0.24 ± 0.22; VM: 0.25 ± 0 .23), within the vastus lateralis muscle (p= 0. 019) and vastus medialis muscle (p= 0. 029). Males also had significantly greater MDF values (82.9 ± 15.7) than females (74.3 ±16.8), but only within the vastus lateralis muscle (p= 0.017). CONCLUSION: To address previous limitations in the literature we recorded HDEMG from three muscles of the quadriceps during isokinetic knee extensions and compared between males and females. Sex differences were noted in mean RMS, intensity and MDF in the VM muscle regardless of speed. However, no differences were detected in other spatial features such as entropy or coefficient of variation unlike previous research. Future studies using decomposition techniques may provide further insight.

P1-P-56 Effects of multi-session tDCS on the excitability of corticospinal and spinal pathways for the soleus

Lynn McCane[1], Jonathan Wolpaw[2], Susan D'Andrea[3], Aiko Thompson[4]
[1]National Center for Adaptive Neurotechnologies and The Univeristy of Rhode Island, [2]National Center for Adaptive Neurotechnologies, Stratton VA, [3]The Univeristy of Rhode Island, [4]Medical University of South Carolina

BACKGROUND AND AIM: Weak transcranial direct current stimulation (tDCS) can modify corticospinal excitability (CSE) acutely (Nitsche and Paulus 2000) and over multiple sessions (Ho, Taylor et al. 2016). TDCS can also enhance motor skill acquisition and retention. For example, tDCS improved skill level and retention in a fine motor hand task in healthy participants (Reis, Schambra et al. 2009) and improved balance training results in fall-risk participants Yosephi, Ehsani, et al., 2018). Surprisingly, little is known about the impact of tDCS on spinal mechanisms that may contribute to improved performance. Several studies have demonstrated tDCS increases transcranial magnetic stimulation (TMS) motor evoked potentials (Jeffery, Norton et al. 2007, Foerster, Rezaee et al. 2018) and leg spinal interneuron activity in resting leg muscles (Roche, Lackmy et al. 2011 & 2012). Here, we aim to characterize the impact of Active (excitatory) or Sham tDCS on the excitability of soleus pathways during standing. METHODS: Fifteen young adults with no known neurological conditions (8 active, 9 females, mean age=26) participated in this study. All measurements were done while the participant maintained a natural standing posture and the corresponding level of soleus EMG activity. Four sessions of excitatory tDCS (2mA anodal, 0.06mA/cm2) are applied over the soleus motor hotspot (determined by TMS) for 30 minutes (mean 3.3 ± 3.6 SD days apart) while five blocks of H-reflexes are collected (1ms square wave pulses in the popliteal fossa). The chronic effects of tDCS on the excitability of soleus H-reflex pathway are assessed with H-reflex/M-wave and MEP recruitment curves (RCs) collected in separate sessions without tDCS before (baseline, BL) and after the four tDCS sessions (post-BL). The results will begin to characterize the effect of excitatory tDCS on lower leg motor pathways in active muscle and may improve its application as an adjuvant to motor skill acquisition. RESULTS: There was no significant difference between BL and post-BL Hmax (normalized to Mmax) within groups (paired t-test, mean BLs 0.42 ± 0.12 and 0.42 ± 0.22, post-BLs 0.41 ± 0.13 and 0.45 ± 0.20, p=0.85 and 0.80, Active and Sham, respectively) or between groups (p-values=0.99 and 0.66, BL and post-BL t-tests). There was also no significant difference between BL and post-BL MEPmax within groups (paired t-test, mean BLs 7.45 ± 2.6 and 5.29 ± 1.5, post-BLs 7.20 ± 5.3 and 7.22 ± 4.3, Active and Sham respectively) or between groups (p-values=0.07 and 0.99, BL and post-BL t-tests). CONCLUSIONS: The results suggest when healthy participants are comfortably standing without task engagement excitatory tDCS has no effect on soleus corticospinal or H-reflex pathways over multiple sessions.

P1-P-57 Exploring electrodermal activity (EDA) as a tool for measuring balance exercise intensity in stroke rehabilitation

Aishwarya Shenoy[1], Towela Tembo[1], Rebecca Todd[1], Janice Eng[1], Noah Silverberg[1], Tzu-Hsuan Peng[1], Courtney Pollock[1]
[1]University of British Columbia

BACKGROUND AND AIM: Regaining walking ability is a priority and is achieved by 80% of stroke survivors; however, falls remain a concern. Improving walking balance post-stroke requires exercises to challenge balance near the limits of the individual's capacity to induce a training effect. However, implementing graded balance challenges is difficult because there are no valid methods for measuring balance exercise intensity. The Rate of Perceived Stability (RPS) Scale is a self-report rating of the balance challenge of an activity and has recently shown promise as a valid measure of balance intensity for people with stroke[1]. Self-report measures can be vulnerable to bias. Validation against biomarkers is needed and may further inform balance exercise intensity measurement. This study explores the relationship between electrodermal activation (EDA; a measure of the autonomic nervous system's 'flight or fight' response that has been used when balance is challenged in people with stroke[2]) and RPS (RPS:EDA) post-stroke during balance challenge tasks. RPS:EDA relationships were compared between tasks reported as high vs. low challenge. METHODS: Participants with chronic stroke (>1-year post) able to walk with or without a walking aid were recruited (n=30). Electrodes placed on the palmar surface of participant's hand captured peak EDA response while they performed tasks from the Community Balance and Mobility (CB&M) Scale, a valid and reliable measure of walking balance post-stroke. Participants rated their perception of balance challenge on each task using the RPS (1-10). Tasks were excluded from analysis if less than 10 participants could perform the task and/or mean task performance score was less than 2/5 on the CB&M Scale. Spearman rank correlations were used to examine the RPS:EDA relationship during 11 tasks. RPS:EDA correlation coefficients were converted to z-scores for comparison between tasks rated low (<5) vs high (≥5) on the RPS. RESULTS: Twenty-eight (14 women) participants (65±10 years) completed the study. Participants had moderate motor impairment and mean self-selected gait speed (0.75 m/s), demonstrative of limited community ambulation. RPS:EDA relationships were weak (rs <0.25) to moderate-to-good (rs 0.50 to 0.75) across all tasks. RPS:EDA relationships were stronger amongst tasks rated at an RPS score ≥5 (rs 0.22 - 0.67) than tasks rated < 5 (p = 0.01). CONCLUSIONS: Physiological anxious arousal (EDA) correlated with self-reported perception of balance (RPS) in chronic stroke as tasks became more challenging. Further research is warranted to

explore this potential multimodal measurement of balance task intensity in stroke rehabilitation. 1. Disabil Rehabil, DOI: 10.1080/09638288.2021.2022777 2. Clin Neurophys 2017, 128, 935-944

R - Sports Science and Motor Performance

P1-R-58 An eight-week, twice-weekly no-load resistance training program promoted neuromuscular adaptations in upper limbs of older adults after detraining period due to COVID-19 lockdown

Rafael Fujita[1], Marina Villalba[1], Kristin Campbell[2], Matheus Gomes[1]
[1]University of São Paulo, [2]The University of British Columbia

BACKGROUND AND AIM: The COVID-19 pandemic forced many older adults to lockdown, stopping their usual physical activities. They experienced a detraining, losing strength and quality of life. To oppose these harmful effects, isometric no-load resistance training (NLRT), can be an interesting alternative to conventional training. Therefore, we aimed to analyze the effects of NRLT in upper limbs' maximum isometric torque and muscle thickness in older adults after COVID-19 lockdown. METHODS: A older woman (ID1-66years, 61.9kg, 158.5cm) and an older man (ID2-66years, 84.1kg, 166.5cm) who were engaged in conventional strength training programs before the COVID-19 lockdown participated in this study. Due to lockdown, they were not practicing strength training for six months. We collected data from participants' dominant limb pre- and post-eight-week, twice-weekly NLRT supervised program. We measured muscle thickness of elbow flexors (brachialis and biceps brachii), and extensors (triceps brachii) using a B-mode ultrasound imaging unit (39mm parallel array transducer-gain of 55dB, depth of 9.2cm, and frequency of 10MHz). We captured one image on a transverse plane for each muscle group. After, we collected maximum isometric torque using an isokinetic dynamometer (100Hz acquisition frequency). The participants performed three MIVC of 5-seconds, with 90-seconds intervals between attempts. During all sessions of the NLRT program the participants were seated with shoulders in an anatomical position, keeping arms beside the trunk, elbows flexed at 90º, and wrists semi-pronated. The verbal instruction "simultaneously co-contract your arm muscles as hard as you can with no movement of your forearm" was given to the participants, who performed five sets of 10 co-contractions of 4-second effort followed by 4-second relaxation, controlled by a metronome app. There was 90-second rest between sets. For data analyses, we measured the muscle thickness using the ImageJ software, considering the distance between the interfaces with the bone and the adipose tissue. For each image, we took three measurements, considering the average as the muscle thickness. The technical error of measurement was 1.70%. For maximum isometric torque, we considered the mean of the peak torques values. RESULTS: ID1 showed increases in muscle thickness of 4.02% for elbow flexors (10.71mm pre; 11.15mm pos) and 8.45% for elbow extensors (12.50mm pre; 13.65mm pos). Similarly, ID2 showed increases of 19.15% for elbow flexors (15.96mm pre; 19.74mm pos) and 19.40% for elbow extensors (15.71mm pre; 19.49mm pos). Regarding maximum isometric torque, ID1 showed decrease of 5.28% for elbow flexion (28.4N.m pre; 26.9N.m pos) and increase of 23.05% on elbow extension (23.7N.m pre; 30.8N.m pos). ID2 showed decreases of 21.53% on maximum isometric torque for elbow flexion (56.2N.m pre; 44.1N.m pos) and 21.89% for elbow extension (51.6N.m pre; 40.3N.m pos). CONCLUSIONS: The NRLT seems to be a good alternative to increase muscle thickness of elbow flexors and extensors muscles. However, NLRT effects were inconsistent for maximum isometric torque.

P1-R-59 Puck speed is related to trunk rotation during ice hockey slap shots

Shawn Robbins[1], Philippe Renaud[1], Neil MacInnis[2], David Pearsall[1]
[1]McGill University, [2]Curv Health

BACKGROUND AND AIM: The slap shot is an essential skill in ice hockey and it is the shot type that produces the highest puck speeds. Trunk rotation is a key element of the slap shot. In golf, increased trunk rotation is associated with faster club head speeds. Similar result were also found during ice hockey wrist shots. However, the contribution of trunk rotation to slap shot performance has not been examined. Therefore, the objective was to determine if trunk rotation was related to puck and blade speed during slap shots in high and low calibre ice hockey players on real ice. METHODS: Male ice hockey players of high (n=10; mean age 26 years) and low (n=9; mean age 26 years) calibre were recruited. A 14 camera Vicon motion capture system sampled at 240 Hz captured the position of reflective markers placed on the players, sticks, and puck. Players were required to complete slap shots that were taken 9.25 m from the net on real ice. They aimed at a target hung in the middle of the net and completed 10 trials. All players used the same type of stick (Nexus 1N, 87 flex, Bauer Ltd). Peak puck and blade speed in the direction of the net were calculated. Trunk angles, with respect to the pelvis, were calculated using an Euler YXZ sequence and the peak trunk axial rotation angle away from the net was identified. Hierarchical linear models examined relationships between puck and blade speed (dependent variables) with group (high vs. low calibre), peak trunk rotation, and their interaction after accounting for control variables (age, body mass index, trial number, skate speed). Data were entered into the model at the trial level and were clustered within each participant. RESULTS: Puck speed was related to the interaction between group and peak trunk rotation (b=0.16, 95% confidence interval=0.01 to 0.31, p=0.034). Higher puck speeds were related to greater peak trunk rotation away from the net (negative values) in the low calibre group, while the relationship was in the opposite direction for the high calibre group (Figure 1). There appears to be less variability in the high calibre group (Figure 1). Blade speed was not related to peak trunk rotation (b=-0.04, 95% confidence interval=-0.09 to 0.00, p=0.054) or the interaction between group and peak trunk rotation (b=0.00, 95% confidence interval=-0.07 to 0.07, p=0.998). CONCLUSIONS: Increased trunk axial rotation away from the net was associated with faster puck speeds in the low calibre group, and thus should be encouraged in these players. The stretch-shortening cycle could account for this finding, whereby trunk muscles are stretched when rotating away from the net and this energy is released when trunk axial rotation changes direction. This relationship was in the opposite direction for high calibre players and these players might rely on other factors to increase puck speed such as stick shaft deformation.

P1-R-60 Influence of low back pain history on lumbopelvic motor control, kinematics and muscle activation during the loaded squatting task in recreational weight lifters

Shih-Tang Su[1], Yi-Fen Shih[1]
[1]*National Yang-Ming Chiao-Tung University*

BACKGROUND AND AIM: Athletes have a high chance of suffering from low back pain (LBP), particularly for those who involve in weight loading sports. The presence of LBP has been shown to impact athletes' sports performance and movement control. For those athletes who have recovered from LBP, some research data showed that altered lumbopelvic control remained. Deficiencies in motor control have been proposed as the most important factor predisposing athletes to recurrent low back injury. However, there has been no study investigating the effect of LBP history on loaded squatting performance and lumbopelvic motor control in recreational weight lifters. The aim of this study is to examine the differences in lumbopelvic motor control, and the kinematics and muscle activation during the loaded squatting task in recreational weight lifters with LBP, LBPH, and asymptomatic controls. METHODS: 45 subjects, 15 in each group are recruited. Participants are recreational weight lifters who have to practice loaded squatting training at least once a week for 1 year. LBP is defined as having the LBP symptoms lasting>24 hrs. LBPH is defined as having no current back pain but suffering from at least 2 previous episodes of LBP separated by a period of at least 2 weeks pain-free or 1 episode lasting more than three months within last year. Asymptomatic controls are those who experience no LBP in the past 2 years. The testing tasks include a series of squatting (4 X 10 repetitions) and a set of lumbopelvic motor control tests. A 2-dimensional video analysis system and a surface electromyography (EMG) system (Noraxon Myomotion) are used to measure lumbopelvic kinematics and EMG of the rectus abdominis (RA), internal oblique (IO), erector spinae (ES), and gluteus maximus (GM). Kruskal-Wallis test and repeated-measures ANOVAs are used to examine group differences with $\alpha=0.05$. RESULTS: Three asymptomatic subjects and four subjects with LBPH are recruited so far. The weight lifters with LBPH had lower motor control score than the asymptomatic group (5.75 vs. 8). Both groups demonstrated greater lumbar flexion (LF), pelvic posterior tilt (PT), and hip flexion (HF) in the 4th set when compared with the 1st set of the loaded squatting task (the LBPH group were 8.23±4.59° vs. 10.92±5.01°, LF; 13.91±5.13° vs. 15.53±4.74°, PT; 112.94±6.38° vs. 112.98±6.76°, HF, and the control group were 7.37±6.04° vs. 8.0±6.44°, LF; 13.82±6.08° vs. 16.44±4.16°, PT; 102.03±2.7° vs. 104.54±0.46°, HF). Compared with the 1st set of the squatting, muscle activities increased with increasing loads (the LBPH group: 42.94±16.56% vs. 62.91±26.94, RA; 35.53±23.19% vs. 43.5±28.44%, IO; 44.88±8.98% vs. 63.42±9.6%, ES; 22.15±4.07% vs. 40.65±7.28%, GM; the control group: 53.95±15.12% vs. 68.91±13.72%, RA; 27±7.25% vs. 42.21±18.54%, IO; 47.11±17.59% vs. 65±8.13%, ES; 19.21±4.32% vs. 26.99±11.19%, GM). No significant group difference was revealed so far. CONCLUSIONS:We plan to complete the data collection of 45 athletes and present the overall results at the ISEK 2022 conference.

P1-R-61 Effects of eight-week of a lower limbs no-load resistance training on neuromuscular parameters in older adults after a COVID -19 detraining period ? Pilot study.

Marina Villalba[1], Rafael Fujita[1], Matheus Gomes[2]
[1]University of Sao Paulo - Ribeirao Preto College of Nursing, [2]School of Physical Education and Sport of Ribeirão Preto, University of São Paulo

BACKGROUND AND AIM: Strength training is one of the main training modalities for strength gains and quality of life in older adults. Due to COVID-19, many older adults stop their usual activities, including physical exercises. Recently, isometric co-contraction training method, or no-load resistance training (NLRT), has been studied and it seems to be an alternative technique to conventional training, showing promising strength gains. NLRT does not use any external equipment/load and can be practiced anywhere. In an attempt to avoid losses of COVID-19 detraining period we aimed to verify the effects of NLRT in lower limbs maximum isometric torque and muscle thickness of older adults while COVID-19 lockdown. METHODS: An older woman (ID1-66 years, 61.9 kg, 158.5 cm) and an older man (ID2-66 years, 84.1 kg, 166.5 cm) participated in this study. They reported being physically active, and they were not practicing strength training programs for at least six months. We collected data from muscle thickness and maximum isometric torque (dominant limb) pre- and post-eight-week NLRT program. We measured muscle thickness from knee flexors (semimembranosus (SM), semitendinosus (ST), biceps femoris long head (BF)), and knee extensors (rectus femoris (RF), vastus intermedius (VI), vastus lateralis (VL), vastus medialis (VM)). For each muscle, we captured one image on a transverse plane. Then, we collected maximum isometric voluntary contraction (MIVC) data of knee extension and flexion at 60º at Biodex, System 4 Pro. They perform three MIVC of five seconds for each condition, with 90 seconds of rest among attempts. After, participants started eight-week, twice-weekly NLRT program. In sessions, participants were seated in a chair with the hip flexed at 90° and the knee at 60°. They performed five sets (90-second rest between sets) of 10 co-contractions (4 seconds of effort followed by 4 seconds of relaxation controlled by a metronome app) for knee flexors and extensors. The verbal instruction was "simultaneously contract your thigh muscles as hard as you can without no movement of leg". For muscle thickness data analyses, we considered the average of three measurements of each muscle using ImageJ software (technical measurement error of muscle thickness was 1,70%, observing reliability of images captured on the same day). We considered the mean of the peak torque values obtained in three MIVC. RESULTS: Regarding muscle thickness (figure1a), ID1 showed increases of 36.49%, 20.46%, and 10.52% of SM, ST, and BF, respectively, and increases of 19.78%, 11.99%, 10.63%, and 12.42% of RF, VI, VL, and VM, respectively. ID2 showed increases of 3.51%, 26.10%, and 18.73% of SM, ST, and BF, respectively, and increases of 35.59%, 0.62%, 10.21%, and 10.81% of RF, VI, VL, and VM, respectively. For MIVC (figure1b), ID1 showed decrease of 1.43% of knee flexion and increases of 2.68% for knee extension. The ID2 showed increases of 12.28% for knee flexion and 2.44% for knee extension. CONCLUSIONS: NRLT seems to increase muscle thickness of knee muscles in older adults. Our MIVC results were inconsistent. Studies with larger samples are needed for better results and conclusions.

Poster Session 2

Friday June 24, 2022

A - Aging

P2-A-1 The effects of age and walking environment on quantitative and qualitative gait measures

Iris Hagoort[1], Nicolas Vuillerme[2], Tibor Hortobágyi[1], Claudine Lamoth[1]
[1]University Medical Center Groningen, [2]Université Grenoble Alpes

Background and aim: Walking performance can be operationalized by quantitative and qualitative outcomes. Covariance across gait outcomes is high, suggesting redundancy and the need to identify independent gait domains that capture unique properties of gait. These gait domains, such as variability, stability, pace, rhythm and symmetry, have often been studied in different environments varying from controlled laboratory settings to uncontrolled natural settings. However, it is unclear how walking environment and age affect gait. Therefore, the aim of the current study was to determine the effects of age and walking environment on an extensive set of quantitative and qualitative gait outcomes.
Methods: Young (n=27, age: 21.6) and older adults (n=26, age: 68.9) walked for 3 minutes in four conditions: walking back and forth on a straight path in a hallway; walking on a specified path, including turns, in a hallway; walking outside on a specified path including turns, and walking on a treadmill in the laboratory. We recorded trunk accelerations in each condition and computed 27 gait outcomes. Using factor analysis, the gait domains 'variability and regularity', 'pace', 'stability', 'time and frequency' and 'complexity' were derived from these gait outcomes. A MANOVA was used to examine the effects of age and environment on these five gait dimensions. The level of significance was set at $P<0.05$. Results: Five factors explained 64% of the variance in gait outcomes. Walking conditions affected all gait outcomes ($p<0.05$). Across the four conditions, there was a group main effect for the 'time and frequency' domain($p<0.05$).There was a group by condition interaction for 'variability and regularity', 'stability' and 'time and frequency' ($p<0.05$). The largest difference between older and young adults occurred in the 'variability and regularity' domain in the hallway straight condition (31%). For the 'stability' and 'time and frequency' domains, the greatest age effect in the treadmill condition (Stability:224%, Time and

Frequency:80%) Conclusion: Walking environment affects all gait domains in both young and older adults. The age by condition interaction suggests that for the gait domains 'variability and regularity', 'stability', and 'time and frequency', treadmill and hallway walking seem to magnify the age-induced changes in gait, implying an enhanced experimental perturbation of gait under these conditions.

P2-A-2 Early muscle activation of the hip abductors in older adults with fall risk

Marcel Lanza[1], Nathan Fakes[1], Vicki Gray[1]
[1]University of Maryland Baltimore

Background & Aim: The ability to generate muscle power requires rapid activation of the muscles. In healthy older adults, those that rapidly activate of the hip abductor muscles step faster. Thus, the ability to rapidly activate the hip muscles early in the movement might have clinical relevance. However, it is unclear if the early activation phases of the hip abductor muscles differ in older adults or those classified as at risk of falls and no-risk of falls. Therefore, the main aim was to compare the early muscle activation phases [measured as electromyography (EMG) amplitude] of the hip abductor muscles during a hip abduction power test in older adults and whether there were differences between fall risk and no-fall risk groups. The secondary aim was to investigate the association between hip abductor EMG amplitude and clinical tests, Stair Climb Power Test (SPCT), and 30-second Chair Stand Test (30CST). Methods: Twenty-two older adults (5 males; 71±4 y; 1.65±0.7 m; 82±18 kg; X±SD) visited the laboratory two times. In the first visit, the participants performed a hip abduction one-repetition maximum (1RM) test on a pneumatic resistance machine (standing position), followed by the 30CST and the SCPT tests. In the second visit, two submaximal tests were performed (10% and 75% of 1RM). Surface EMG sensors were positioned over the gluteus medius (GM) and tensor fascia latae (TFL) muscles, using Seniam and the EMG was processed based on ISEK guidelines. EMG amplitude from the 75% of 1RM was calculated from 0-100 and 100-200 ms of the GM and TFL from EMG onset. The EMG for the 75% 1RM was normalized by the EMG calculated over the entire 10% 1RM contraction. Individuals were classified as at risk of fall (n=8) or no-risk of fall (n=14) based on the 30CST score. Two-way repeated measures Anova between subjects were used to compare EMG. Spearman correlations were performed to examine the association between EMG and the SPCT and 30CST tests. Statistical analyses were performed using SPSS, and the significance level was set at $P \leq 0.05$. Results: Independent of fall risk group, GM and TFL EMG was 4% higher at 100-200 ms than at the first 100 ms ($p<0.001$) during the hip power test (Figure 1A and B). Although, the early EMG amplitude of the older adults classified as no-fall risk were quantitatively higher (~2%) for both muscles compared to risk of fall group, no significant statistical difference was found. Furthermore, GM EMG amplitude at both time points (0-100 /100-200 ms) was correlated with the 30CST score ($P \leq 0.33$) but not the SCPT. Conclusion: The ability to rapidly activate the hip abductors (GM and TFL) during a hip abduction power test increases with time but seems to be similar between older adults classified with risk of fall or non-risk of fall. Nonetheless, higher activation of the GM was associated with the score on the chair standing test. In conclusion, improving the ability to quickly activate the GM muscle may help older adults better perform daily life tasks like standing from a chair.

P2-A-3 Motor unit firing rates in young and very old adults during isokinetic fatigue and recovery

Alexander Zero[1], Eric Kirk[1], Kevin Gilmore[2], Charles Rice[1]
[1]University of Western Ontario, [2]University of Toronto

BACKGROUND AND AIM: Age-related remodeling of motor units (MU) over decades of life results in larger and fewer MUs in human limb muscles. Likely, these changes contribute to sarcopenia and directly or indirectly to lower MU firing rates at high (>50% maximum voluntary isometric contraction) intensities. However, unlike in isomeric contractions, during maximal effort dynamic contractions in older adults firing rates are minimally different despite older adults producing less power than young adults. During moderate to high intensity isometric fatiguing tasks, older adults show a similar decline in firing rates as young adults, but because of task specificity as an important factor in fatiguability, it is unknown how firing rates will change in response to fatiguing concentric contractions. Thus, the purpose was to compare MU firing rates between young adults (19-33y, n=8) with old adults (78-93y, n=11) using an isokinetic (controlled velocity of movement) fatiguing task which mitigates some differences in relative age-related fatiguability. METHODS: Each contraction was a maximal effort and repetitive elbow extension contractions were done at 25% of maximum limb movement velocity. From the anconeus muscle, we recorded single MUs using intramuscular fine wire electrodes. The fatiguing task was terminated when power (torque x velocity) was reduced by ~35%. Recovery from task failure was assessed for 10 minutes. We hypothesized the number of contractions to task-failure would be similar across age groups and that MU firing rates would decline and recover equally in both groups. RESULTS: A total of 22 and 19 MUs were recorded during the fatigue protocol for the young and old groups, respectively. However, only 16 MUs in the young group were followed during the 10-minute recovery period. For baseline isokinetic contractions, MU firing rates were similar between young (~26 Hz) and older (~25 Hz) adults. The number of contractions to task-failure were comparable between young (~41) and older (~44) adults. At task-failure (~35% power loss), MU firing rates decreased similarly ~31 and ~28% for the young and old, respectively. Elbow extensor power and anconeus MU firing rates in both groups were fully recovered by 5 minutes. CONCLUSIONS: We observed no age-related effect in MU firing rates when similar muscle fatigue was induced through slow (~44-52°/s and ~39-50°/s for young and old, respectively) maximal effort isokinetic contractions. These results suggest that despite lower power production in older adults, firing rates respond similarly to young adults during fatiguing concentric contractions. This highlights the effect of contraction modality (task) on fatigability and indicates firing rate control in a presumed remodeled MU pool is similar to young adults. Supported by NSERC

C - Biomechanics

P2-C-4 The Effect of Adjusting Frontal Plane Knee Alignment when Scaling Patient-Specific Neuromusculoskeletal Models in Patients with Knee Osteoarthritis

Dominique Cava[1], Trevor Birmingham[1], Kristyn Leitch[1], Ryan Willing[1]
[1]*Western University*

BACKGROUND AND AIM: The pathogenesis of knee osteoarthritis (OA) is complex and includes aberrant mechanical loads across the tibiofemoral joint during ambulation. Although joint loads cannot be directly measured in the intact knee, patient-specific EMG-assisted computational neuromusculoskeletal models offer a means to estimate these loads. Importantly, the distribution of loads on the knee is affected by lower limb frontal plane alignment (a known risk factor for OA progression), yet standard musculoskeletal models often do not account for alignment. The purpose of this study was to compare preliminary results from standard and alignment-adjusted patient-specific EMG-assisted computational neuromusculoskeletal models in patients with medial compartment knee OA and varus alignment. METHODS: Kinematic and kinetic gait data from three patients (age=53±4 years; 2 males and 1 female)

with symptomatic and radiographic (KL grade 2 or 3) knee OA primarily affecting the medial compartment of the tibiofemoral joint (mechanical axis angle=5.1°±1.9° varus) were collected during walking. With these data, two generic models were scaled in OpenSim for each patient. The first "standard model" underwent a standard method of scaling using the patients' anthropometric data from a static trial. The second "alignment-adjusted" model was first corrected to match frontal plane knee alignment (i.e., mechanical axis angle) measured from hip-to-ankle standing radiographs before scaling to the patient's anthropometric data. Kinematic and kinetic data from both models were provided as inputs to an inverse dynamics analysis. Both standard and alignment-adjusted computational EMG-assisted neuromusculoskeletal models were then executed in CEINMS with experimental activations and OpenSim computed knee flexion external torques as inputs. CEINMS estimates excitation patterns for musculotendon units from which EMGs cannot be experimentally measured and adjusts EMG linear envelopes that may be subject to measurement errors, while simultaneously ensuring dynamical consistency in predicted internal joint moments. Computed muscle activations and knee flexion internal torques were compared to corresponding experimental muscle activations and OpenSim computed external torques to provide an overall measure of the model's prediction accuracy. RESULTS: The root mean square error (RMSE) between computed and experimental muscle activations for all muscles (%MVIC) using the standard model was 0.15 and decreased to 0.14 (7% lower) for the alignment-adjusted model. The RMSE between internal and OpenSim computed external knee flexion torques (Nm) using the standard model was 1.38 and decreased to 0.18 (87% lower) for the alignment-adjusted model. CONCLUSIONS: Frontal plane knee alignment is an important yet often neglected parameter in musculoskeletal model predictions. Preliminary results suggested that adjusting knee alignment improved model prediction accuracy in patients with knee OA.

P2-C-5 Investigating the effect of gait speed on joint loading distribution in knee osteoarthritis (KOA) individuals during walking: preliminary results

Hananeh Younesian[1], Katia Turcot[1]
[1]*Faculty of Medicine, Laval University, Quebec, Canada; Center for Interdisciplinary Research in Reha*

BACKGROUND AND AIM: Knee osteoarthritis (KOA) is a chronic degenerative joint disease that is associated with altered joint loading. Usually, gait speed among individuals with KOA declines due to the pain and functional limitations. Individuals with KOA develop gait strategies followed up by the change in the joint loading distribution potential for the faster progression of an existing KOA and onset of osteoarthritis at joints adjacent to the knee. Therefore, with the inconstant walking speed in the ecological environment, and the secondary gait changes observed in KOA individuals, it is important to study the impact of different gait speeds on the lower extremity joint loading distribution at the affected and contralateral sides. The aim of this study is determining how gait speed affects the strategies developed by knee OA individuals and thus their lower limb joint loading distribution. METHODS: 15 knee OA (10 f/5 m) individuals (age: 66± 7 years old (y), Body Mass Index (BMI): 29.9 ± 6.1) walked two minutes on the instrumented treadmill (Bertec, Columbus, OH, US, 1000Hz) at three different speeds (self-selected walking speed (SSWS), 20% faster and slower than SSWS). The first 10 gait cycles collected after 30 seconds of trial was chosen for analysis. Gait kinematics and kinetics were being recorded using 9 VICON cameras and two forces plates embedded into the treadmill. Forty-three markers were attached to the skin based on the International Society of Biomechanics configuration and combined to the musculoskeletal modeling (MSK) in OpenSim and MotionMonitor. For hip and knee joints, the 1st peak of frontal and sagittal moments and contact forces have been estimated and averaged from the

selected gait cycles. RESULTS: Preliminary results for three OA participants (age: 69± 2 y, BMI: 25.4 ± 1.7, SSWS: 0.8± 0.1) demonstrated that the 1st peak of moments (N.m/Body Mass(Kg)) for the hip in the frontal plane in the limb with OA was: 0.55± 0.11(SSWS), 0.38± 0.17(fast) and 0.36± 0.17(slow) while for the contralateral limb was: 0.46± 0.10(SSWS), 0.61±0.29(fast) and 0.34±0.27(slow). The 1st peak knee adduction moment (KAM) for the limb with OA was: 0.22±0.10(SSWS), 0.17±0.05(fast) and 0.20 ± 0.09(slow), while for the contralateral limb was: 0.26±0.10(SSWS), 0.19±0.10(fast) and 0.17±0.09(slow). The 1st peak medial knee contact force (N/BW) in the limb with OA was: 3.47±0.92(SSWS), 3.58±0.97(fast) and 3.45±1.25(slow), and for hip, 2.89±1.39(SSWS), 3.55±1.23(fast) and 3.53±1.41(slow). CONCLUSIONS: First results showed faster walking increased joint contact forces in the affected side. The Abd/Add moments in hip and knee joints at both sides, have not increased necessarily while increasing the gait speed. However, further analysis is necessary to define the effect of gait speed on joint loading distribution in KOA individuals. This study could be used for defining the potential risk of the OA progression and onset in lower extremity joints.

P2-C-6 Waveform analysis of forearm muscle activity during dynamic wrist flexion and extension: Effects of forearm posture and torque direction

James Parkinson[1], Davis Forman[2], Garrick Forman[1], Alan Cudlip[1], Shawn Beaudette[1], Mike Holmes[1]
[1]Brock University, [2]University of Guelph

Background and Aim: The wrist extensor muscles often exhibit elevated muscle activity across tasks (relative to the flexors). Popular analysis techniques evaluate discrete time points during isometric grip [1] and dynamic wrist movements [2, 3] to obtain average muscle activity. Considering the complex anatomical and biomechanical differences across forearm muscles, these measures may not capture changes in activity during hand movement. The purpose of this study was to determine posture and torque application effects on forearm muscle activity using waveform analysis. Methods: 12 participants performed a controlled wrist flexion/extension (±40°) tracking task with their dominant arm using a wrist manipulandum (Wristbot, Genoa, Italy) in a neutral, 30° pronated, or 30° supinated forearm posture. Wristbot applied torques resisted wrist extension or flexion relative to 15% of maximal wrist extension force. Torque-posture combinations resulted in six conditions, with six flexion/extension repetitions performed per trial. Surface electromyography (EMG) of the flexor carpi radialis (FCR), flexor digitorum superficialis (FDS), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR), extensor digitorum (ED), and extensor carpi ulnaris (ECU) were recorded during each trial. Wrist kinematics were tracked using the Wristbot, and EMG was time normalized (0-100% representing one flexion/extension cycle), low pass filtered (dual pass 2nd order Butterworth, 3 Hz cut-off) and normalized to maximal voluntary contractions (%MVC). Statistical parametric mapping analyzed waveforms for each muscle using a two-way repeated measures ANOVA for simple main effects (p=0.05), with post-hoc t-tests. Results: All muscles showed main effects for both posture and torque direction. Decreases in activity were observed in non-neutral forearm postures (53-70% and 5-23% of the movement in pronation/supination, respectively) (Figure 1). When compared to the extension torque direction, the flexion torque increased activity for FCR, FDS, and FCU for 100%, 9-81%, and 22-51% of the movement, respectively. ED and ECU had significantly increased activity during 0-26% and 70-100% of the movement, during the same torque direction. Conclusion: When evaluating the entire waveform, deviating from a neutral forearm posture decreased activity for all muscles during specific ranges, contradicting previous findings [3]. Agonist lengthening with forearm rotation could require greater activation to achieve the intended movement. Waveform analysis demonstrates complex forearm muscle activity patterns, even during a relatively

simple flexion/extension movement. Using this technique to explore more complex hand movements could provide insight into performance, fatigue and injury progression. References 1. Mogk, J., & Keir, P. (2003). Ergonomics, 46(9), 956-975 2. Forman, D.A. (2020a). J Biomech, 108, 109897 3. Forman, D.A. (2020b). J Biomech, 108, 109908

P2-C-7 Influence of gravity on control strategies of the muscles of the upper limb

Elisa Romero Avila[1], Wolfgang Potthast[2], Catherine Disselhorst-Klug[1]
[1]Institute of Applied Medical Engineering, RWTH Aachen, [2]Institute of Biomechanics and Orthopaedics, German Sport University Cologne

Movements of the human body are produced by complex interactions of the musculoskeletal system that involve neuromuscular control strategies. Additionally, external forces (e.g. the gravitational force) have a paramount influence on the generation and coordination of muscle forces needed for a given motor task. Regarding the muscular coordination patterns of the biceps brachii, brachioradialis, and triceps brachii during elbow flexion and extension movements, each muscle contributes differently to movement control against gravity depending on the type of muscle contraction, joint angle, angular velocity, and the anatomical plane along which the movement takes place. Since more than one muscle is involved in a single elbow movement, it represents muscle redundancy. This work aims to analyze the differences in muscular activation patterns during elbow flexion and extension movements under conditions where the gravitational vector is parallel to the direction of motion (sagittal plane), compared to conditions where the gravitational vector is perpendicular to the direction of motion (transverse plane). Muscular activation of the biceps, brachioradialis, and triceps was recorded during elbow flexion and extension movements at different angular velocities performed in the transverse and sagittal plane. In both conditions, the muscles worked against a constant external torque over the entire range of motion and acted in the direction of elbow extension. Furthermore, the effect of gravitational force was compensated by an external support. For this study, 20 healthy subjects (10 male, 10 female, age 33,2 ±10,6 years) were recruited. To determine elbow joint position, angular velocity, and movement direction, a 3D motion capture system was used. The resulting sEMG envelopes were categorized according to a decision tree algorithm which addressed the type of contraction, joint angle, and angular velocity. The results showed that, in both conditions the biceps and brachioradialis have similar muscular activation patterns during concentric contractions with increasing sEMG envelope as angular velocity increases. During eccentric contractions in both conditions, the sEMG envelope of the biceps decreases while, in contrast to the biceps, the sEMG envelope of the brachioradialis increases with increasing angular velocity. Moreover, regardless of angular velocity, an unexpected statistically significant increase in the sEMG envelope of all three muscles was found when the measurements were performed in the transverse plane. This increase in the sEMG envelope can be attributed to muscular co-activation. Since the subjects are less familiar with flexion and extension of the elbow in the transverse plane compared to movements in the sagittal plane, less well-entrenched neuromuscular coordination patterns are applied. This includes muscular co-activation to improve the joint´s stability and meet the task's purpose, particularly as the angular velocity increases.

P2-C-8 Kinematic difference between right and left turns (Pirouette) in a classical ballet with pointe shoes

Yurina Tsubaki[1], Yui Kawano[2], Connie Lin[3], Mayumi Kuno-Mizumura[1]
[1]Ochanomizu University, [2]Japan Institute of Sports Sciences, [3]National Cheng Kung University

BACKGROUND AND AIM: Pirouette is a ballet turn performed by balancing the body on one leg, which is frequently performed onstage. Dancers generally have a preferred direction of turning, but professional dancers need to turn in both directions while wearing pointe shoes, which comprise multiple layers and are strong enough to support the entire body weight on tiptoes. Biomechanical research on pirouettes has primarily focused on the number of turns and joint angles. However, a few biomechanical analyses of pirouettes have been conducted with the help of professional ballet dancers wearing pointe shoes. Therefore, this study aimed to analyze the differences in the kinematic parameters of the right and left pirouettes of professional ballet dancers. METHODS: Seven female professional ballet dancers participated in this study. Thirty-three reflective markers were attached to the subjects, based on the Plug-in-Gait model, and wearing pointe shoes, they performed a single pirouette with right and left turns. The movements were captured using eight optical cameras (Vicon MX; 250 Hz), and the ground reaction force (GRF) was measured using a force plate (Kistler, 1000 Hz). We obtained three successful trials for both the right and left turns. Using a three-dimensional motion analysis device (Vicon Motion Systems), the maximum GRF, lower limb moment and peak moment times were analyzed during the initial phase of the pirouette. Paired t-tests were conducted to evaluate the differences in the maximum GRF, lower limb moment and peak moment times between the right and left turns. RESULTS: All the subjects preferred the right turn. The maximum GRF during a right turn in the vertical and rotational directions on the support side was significantly lower in a left turn (right turn: 8.8 ± 2.0 N/kg for the vertical direction and 2.8 ± 0.6 N/kg for turn direction; left turn: 10.6 ± 1.8 N/kg for the vertical direction and 3.6 ± 0.5 N/kg for turn direction). The maximum ankle plantar flexion moment on the supporting side was 1.0 ± 0.3 Nm and 1.2 ± 0.3 Nm for the right and left rotations, respectively. In addition, the maximum hip internal rotation moment was significantly higher for the right rotation (0.7 ± 0.3 Nm) than for the left rotation (0.5 ± 0.2 Nm). There were no significant differences in the timings of the peak moments. CONCLUSIONS: This study implied that dancers were able to generate hip joint moments to turn effectively when they performed preferred direction. A previous study showed that the greater the number of turns performed, the higher the hip moments produced. In addition, the experienced dancers extended their lower limb joints from the hip to the ankle, but the beginners did not do so, during the pirouette. While the task was only a single pirouette in the current study, the subjects generated larger hip moments with a smaller maximum GRF during the preferred turns than in unpreferred turns. Considering these facts, the dancers were able to perform pirouettes effectively by adjusting their hips and by producing power during their preferred turn; however, the unpreferred turn was not performed as sophisticatedly as the preferred turn.

P2-C-9 Detecting differences in gait initiation between older adult fallers and non-fallers through time-series principal component analysis (PCA)

Kaya Yoshida[1], Drew Commandeur[2], Sandra Hundza[2], Marc Klimstra[2]
[1]Rehabilitation Research Program, University of British Columbia, [2]University of Victoria

BACKGROUND AND AIM: Gait initiation (GI) is an important locomotor transition task that includes anticipatory postural adjustments and the joint propulsion necessary for the first step of walking. Discrete variable analysis between GI of fallers and non-fallers has shown between-group differences for fall risk identification. However, more complex approaches, such as time-series principal component analysis (PCA) may allow the examination of changes not detectable using discrete comparisons alone. This study aims to characterize the differences between fallers and non-fallers by examining the kinematics and kinetics of gait initiation using time-series PCA. METHODS: A sample of 56 community-

dwelling older adults completed five walking trials where GI was measured by force platforms. PCA of centre of pressure kinematics and kinetics time-series data were measured, and multivariate analysis of covariance was used to compare the individual loading scores of each principal component between groups. RESULTS: Fallers demonstrated differences in the range of mediolateral movement during weight transfer, differences in anteroposterior force development, and a more gradual rise in vertical forces in the first step, associated with a shorter first step length. CONCLUSIONS: Time-series PCA helped to highlight differences not detectable using discrete analysis alone. Specifically, fallers appear to prioritize minimizing instability over forward progression performance, compared to non-fallers.

P2-C-10 Evaluation of knee Helical Axis dispersion during walking after isometric muscle training

Corrado Cescon[1], Paola Adamo[2], Francesco Oddenino[2], Federico Temporiti[2], Roberto Gatti[2], Marco Barbero[1]

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

BACKGROUND AND AIM; Different types of muscular training create different metabolic stress and muscular adaptations. Strength training could modify displacement of knee center of rotation (CoR) during movement, which can be estimated through Helical Axes (HAs) dispersion. The primary aim of the study was to describe knee HAs dispersion during walking after two different strength training in healthy subjects. The secondary objective was to assess the physiological variability of knee HAs dispersion. METHODS; Thirty young subjects (22.6±2.1 years) were randomized in two groups: MT group performed quadriceps and hamstrings isometric contractions at 90% of the MVC, RT group at 30%. All participants were asked to walk on a treadmill at spontaneous speed during two different recording sessions, seven days apart (T0-T1pre). After the second evaluation (T1pre), they underwent the first training and they were re-assessed immediately after that (T1post). Subsequently, they underwent 2 weeks of training and, in the last session, they performed the last evaluation, before and after the last training (T2pre-T2post). The gait phases were identified using the position of markers placed on both heels and toes. Helical axis were computed for each knee joint during 100 steps on the treadmill. Knee HAs dispersion was quantified using mean distance (MD) and mean angle (MA). RESULTS; No differences between group over time were found for MD and MA in dominant and non-dominant side ($p>0.05$). Inter-session reliability was good/excellent for both MD and MA in sagittal plane (ICC ≥ 0.74 except one ICC= 0.70). The figure below represents an example of Helical Axes dispersion during 100 gait cycles. Different colours represent different stride phases. CONCLUSIONS; Resistance and maximal strength training do not modify knee HAs dispersion during walking in young, healthy subjects. MD and MA are reliable HAs dispersion parameters which can be used to quantify knee CoR displacement during lower limb movements.

D – Brain Imaging

P2-D-10 Lateralized beta modulation is related to arm swing in human gait

Marzieh Borhanazad[1], Nadia Dominici[1], Andreas Daffertshofer[1]

[1]Vrije Universiteit Amsterdam

BACKGROUND AND AIM: Arm swing is known to support gait stability. Here we studied whether this is merely due to biomechanical factors or whether cortical activities related to arm swing also corroborate with those related to the overall gait pattern. METHODS: Twelve subjects walked on a treadmill at three controlled speeds (3, 4 and 5 km/h), either with natural arm swing or with arms crossed, while whole-head EEG (64 channels), ground reaction forces and body kinematics were recorded simultaneously. The EEG signals were preprocessed via band-pass filtering and artifact rejection based on independent component analysis. Subsequently, we used Morlet wavelets to compute the time-frequency representation of every channel, segmented into strides, and time-normalized them. We concentrated on the beta frequency band (15-30 Hz) and estimated cortical sources around the gait events (left/right heel strike and toe-off) via dynamical imaging of coherent sources beamformers. For statistical evaluation we adopted a 2×2×2 ANOVA design: condition (with/without arm swing) × step event (heel strike/toe-off) × side (left/right). RESULTS: The beamformer results showed significant beta activation in premotor and sensorimotor areas. Significant main effects were present both heel-strike/toe-off and left/right contrasts, but not in with/without arm swing. Interestingly, we found a significant condition × step event × side interaction localized in left (pre-) motor areas. CONCLUSIONS: The contribution of beta band oscillations well documented, especially for motor performance of the upper extremities. The cyclic movement of the end-effectors during gait is largely phase-locked, which is accompanied by strongly coupled muscle activities. This gives rise to the notion of muscle synergies and/or muscle networks that arguably stem from common neural input. One may hypothesize that here beta oscillations play an important role. Yet, this is unclear as to whether beta activity really forms that common neural input or whether it serves to entrain the motor network, and channel its output at isolated moments in time. Our results point at the latter. We observed left-lateralized beta activity when comparing heel-strike with toe-off contrasts at either left or right steps. This differential lateralization seemingly disappeared when the arms were crossed. Earlier studies in upper extremities revealed such a lateralization to increase with increasing task complexity/accuracy demands. As such we speculate that heel-strike and toe-off events come with differential timing demands for the arm swing to be beneficial. If true, this may readily explain the absence of the left dominant activity when arms are crossed.

P2-D-11 From lab to nature: assessment of brain-body interactions in naturalistic conditions using wireless EEG-EMG amplifier

Alessandra Giangrande[1], Giacinto Luigi Cerone[2], Alberto Botter[2], Harri Piitulainen[1]
[1]University of Jyväskylä, [2]Politecnico di Torino

BACKGROUND AND AIM: Instrumentation for simultaneous acquisition of electrophysiological (EEG, EMG) and biomechanical signals is often wired, non-wearable, prone to movement artifacts and limited in use to static tasks in laboratory environments. EEG recordings during dynamic tasks, such as gait, are usually done on a treadmill or with bulky instrumentation that may alter the natural gait. Due to these methodological limitations, the corticospinal mechanisms of motor control are still understudied in naturalistic dynamic conditions. Recently, we proposed a wireless, miniaturized EEG acquisition system that was validated during conventional static conditions [1]. We aimed to demonstrate its use as part of a wireless Body-Sensor Network capable to simultaneously record several bio-signals during naturalistic gait. METHODS: We synchronously recorded: 30 EEG channels [1], EMG of right/left tibialis anterior and soleus muscles (DuePro, OT Bioelettronica, Italy), 3-axis foot acceleration and foot-switch signals from sensors on the heel and the distal metatarsal head of each sole. Five healthy subjects performed straight overground walking at self-selected speed for 60 s. In time domain, cortical evoked responses to the right and left heel strikes were averaged separately to quantify the cortical activity related to the "onset" of the gait cycle. In time-frequency domain, baseline-corrected event-related-spectral perturbation (ERSP) [2] was computed to estimate the cortical power modulations induced during the gait cycle. In frequency domain, cortex-muscle coherence was computed between the EEG and EMG

signals during the stance phase (i.e. from heel strike to toe off) [3]. RESULTS: No relevant gait-related artifacts were detected in the EEG recordings. After heel strike, a clear somatosensory evoked response was detected in the primary sensorimotor cortex. ERSP showed similar cortical power modulation patterns in the sensorimotor cortices as shown earlier [4]: bilateral alpha (8-14 Hz) and beta (14-30 Hz) suppressions just before left/right heel strikes were followed by power enhancements. Cortex-muscle coherence peaked at beta band over the contralateral primary sensorimotor cortex of the foot in line with previous evidence [5]. CONCLUSIONS: Our results support the previous findings that the human cortex is involved in the motor control and somatosensory processing even in one of the most automated dynamic human motor actions, the gait. This corticospinal coupling was further demonstrated with significant cortex-muscle coherence. Our novel wireless EEG system was robust against artifacts, interfaceable with simultaneous recordings of EMG and biomechanical signals, and thus is feasible to study comprehensively the sensorimotor system in minimally restricted naturalistic conditions, thereby providing new insights in the human neocortex functions. REFERENCES: 1. Cerone et al. 2022, IEEE TNSRE, 10.1109/TNSRE.2022.3140220 2. Grandchamp et al. 2011, Front Psychol 2, 1-14 3. Halliday et al. 1995, Prog Biophys Molec Biol. 64, 237-78 4. Roeder et al. 2018, J Neurophysiol 120, 1017-31 5. Petersen et al. 2012, Physiol. Soc. J Physiol 590, 2443-52

P2-D-12 Standing on a biomimetic surface forces the involvement of sensorimotor cortical territories

Chloe Sutter[1], Marie Fabre[1], Jean Blouin[1], Laurence Mouchnino[1]
[1]CNRS Aix Marseille Université

BACKGROUND AND AIM: A main challenge in motor control is to understand the mechanisms underlying the sensorimotor transformation of sensory inputs into postural reaction when equilibrium is jeopardized by the displacement of the support under our feet. Surprisingly, most of the investigations in this field have ignored the behaviour of the surface/body contact mechanics. Being the first to be stimulated by this relative movement evoking a mechanical friction (i.e., shear forces), the plantar skin receptors (i.e., mechanoreceptors) are one of the main contributor to the postural reaction. In this light, their stimulation most likely depends on the physical characteristics of the supporting surface. We hypothesized that a biomimetic surface complying with the characteristics of the mechanoreceptors and skin dermatoglyphs (i.e., biomimetic) would facilitate the cortical processes of the tactile inputs. METHODS: To test our hypothesis, we measured the amplitude of the somatosensory potential (i.e., P1N1 SEP) evoked by unexpected but gentle supporting surface translation (mean peak acceleration of 0.07m.s-2). 15 subjects stood with the eyes closed on either a biomimetic or on smooth and grooved control surfaces. We reasoned that the amplitude of P1N1 measured over the primary somatosensory areas (S1) should be a key variable for comparing the amount of sensory inputs reaching the cortex. RESULTS: The amplitude of the SEP was greater when standing on the biomimetic surface compared to the control surfaces ($F(2,28)= 3.55$, $p= 0.04$) and the postural task then appears less challenging (i.e., lower theta band activity). Moreover, EEG source localisation showed greater activation of the superior parietal lobule (SPL) and extrastriate body area (EBA) when standing on the biomimetic surface. These regions are known to be involved in body representation, sensorimotor integration, and action preparation (1). On the other hand, standing on the control surfaces lead to increased activation of inferior parietal lobule (IPL), dorsolateral prefrontal cortex (DLPFC) and posterior cingulate cortex (PCC), areas involved in the mobilisation of attentional resources (2). CONCLUSIONS: Overall our results showed that standing on a biomimetic surface involved a sensorimotor network that should be more effective for postural responses to be prepared when balance demand is challenged. (1) Kühn et al (2010). J Cog Neurosci 23: 214-220/ Mohan et al (2018). Neurosci 368 : 240-245. (2) Luks et al (2007). NeuroImage 35: 949-958/ Leech & Sharp (2014). Brain 137:12-32.

E – Clinical Neurophysiology

P2-E-13 Corticomotor control of lumbar erector spinae in preparation of a postural motor tasks

Mikaël DESMONS[1], Amira Cheriff[1], Antoine Rohel[1], Catherine Mercier[1], Hugo Massé-Alarie[1]
[1]*CIRRIS*

Background: Anticipatory postural adjustments (APA) are critical for postural control and inherent to most voluntary movements. Lumbar erector spinae (LES) are activated in advance to ballistic shoulder flexion. Different neural circuits are involved in the preparation and execution of LES. Roughly, premotor regions are involved in motor preparation and the primary motor cortex (M1) is involved in movement execution. Transcranial magnetic stimulation (TMS) may activate different neuronal circuits by changing the direction of the coil. While the posteroanterior electrical current in the brain (PA) depolarizes mainly interneurons in M1, an anteroposterior current (AP) is suggested to probe neurons from premotor. The corticospinal excitability of the LES during motor preparation and execution of APA may be different when assessed with PA- and AP-TMS. Objective: The aim of the study is to determine the effect of the current direction (PA- vs, AP-TMS) on the corticomotor control during motor preparation and execution of a task eliciting APA of LES. Methods: Eight healthy participants have been recruited. Electromyographic (EMG) electrodes were positioned on the LES. PA and AP-TMS were tested during a 'motor planning' paradigm. A Warning signal informed participants to prepare to flex their shoulder at the Go signal occurring 1500 ms later.. Single pulse TMS (120% of active motor threshold [AMT]) and paired pulse TMS (conditioning and test stimuli at 80% and 120% AMT respectively, with interval interstimulus of 3ms) were randomly applied while waiting the Warning signal (baseline), at 250ms before the Go signal (Motor preparation period) or 30ms before the onset of the EMG burst of the LES (Motor execution period). Results: Similar motor evoked potential (MEP) amplitude modulation was observed between PA and AP-TMS for single and paired-pulse TMS. For single pulse, MEP amplitude was smaller in the Motor preparation (0.12(0.05)mV - $p=0.01$) and larger in the Motor execution (0.18(0.06)mV - $p=0.01$) compared to baseline (0.13(0.06)mV) regardless of current direction (main effect: Condition | $F=12.41$; $p<0.001$). MEP amplitude was larger in the Motor execution compared to Motor preparation period ($p<0.001$). For paired-pulse TMS, less SICI was observed during Motor execution (87.10(15.30) %test) compared to Motor preparation (70.25(16.15) %test - $p=0.03$) and to the baseline (65.89 (15.21) %test - $p=0.01$) regardless of the current direction (main effect: Condition | $F=8.30$; $p<0.001$). In addition, less SICI was present in PA- than in AP-TMS regardless of the conditions (main effect: Direction | $F=6.44$; $p=0.01$). Discussion: The neural circuits recruited by PA- and AP-TMS behave similarly in the preparation and execution of a movement eliciting APA of LES. AP- and PA-SICI circuits could be involved in the regulation of corticospinal excitability. Studies with larger sample size will allow to confirm if AP- and PA-SICI have a similar functional role in motor preparation/execution.

P2-E-14 Effect of subcortical neuromodulation on cortical stimulation induced motor output: a probe of subcortical motor pathways?

Paul Stapley[1], Jonathan Shemmell[1]
[1]*University of Wollongong*

BACKGROUND AND AIMS: The reticulospinal and vestibulospinal tracts are known to play a key role in the control of posture and balance yet are difficult to directly assess in humans due to their subcortical origin. However, cortico-reticulospinal contributions to responses elicited by dirrect stimulation of the motor cortex are shown to occur ~10 ms later than those driven by corticospinal input in monkeys (2). We hypothesized that the area of late responses (10-30 ms after response onset) but not early responses (0-10 ms after response onset) to cortical stimulation in the upper limb would significantly increase in amplitude when cortical stimulation was combined with acoustic startle (AS); galvanic vestibular stimulation (GVS) or both. METHODS: Transcranial magnetic stimulation (TMS) was applied to the motor cortex of participants (n = 7) targeting the upper-limb. EMG activity was recorded during isometric contractions (5% MVC) of the first dorsal interosseous and biceps brachii muscles. Motor evoked potentials were produced and response area quantified across conditions combining TMS with acoustic startle (115dB), GVS or both.` RESULTS: A one-way repeated measures ANOVA shows that late responses differed significantly across stimulation conditions ($F = 2.81$, $p = 0.027$) whereas early responses did not change. Post-hoc t-tests revealed an increase in the area of the late response when TMS was combined with AS only, and only in the biceps brachii (tstat = -4.32, p = < 0.001). A regression analysis showed that there was no relationship between the change in amplitude of the early and late responses (R2 = 0.0524, $p = 0.62$). CONCLUSION: These results support the idea that the reticulospinal tract is activated by TMS in humans and that it is involved in the transmission of the late component of upper limb muscle responses to TMS. TMS may be a viable tool to assess the state of the reticulospinal tract in humans. 1. Peterson, B.W., 1979. Reticulospinal projections to spinal motor nuclei. Annual review of physiology, 41(1), pp.127-140. 2. Fisher, K.M., Zaaimi, B., Edgley, S.A. and Baker, S.N., 2021. Extensive cortical convergence to primate reticulospinal pathways. Journal of Neuroscience, 41(5), pp.1005-1018.

P2-E-15 Does obesity interfere with the stomatognathic system of children?

Isabela Regalo[1], Ligia Gonçalves[1], Paulo Vasconcelos[1], Jaime Hallak[1], Paula Castelo[2], Marcelo Palinkas[1], Simone Regalo[1], Selma Siessere[1]
[1]USP, [2]UNIFESP

BACKGROUND AND AIM: Obesity is a problem of worldwide concern. In 2025, it is estimated that 75 million children around the world will be obese. This observational study evaluated obese children (7 to 11 years old; n = 20) and eutrophic individuals (n = 20) matched by age, sex and height. The physical examination allowed classifying the individuals into eutrophic and obese. The aim of this study was to evaluate the electromyographic activity and the thickness of masticatory muscles of obese children. METHODS: The masseter and temporal muscles were evaluated with Delsys Trigno TM wireless electromyograph. The children were assessed in the following mandibular tasks: rest, protrusion, right laterality, left laterality and maximum voluntary contraction with parafilm. The maximum voluntary contraction was used to normalize the data. The portable ultrasound device (NanoMaxx; SonoSite) was used to measure the thickness of the masseter and temporalis muscles fibers at rest and dental clenching in maximal voluntary contraction. The data were analyzed statistically by independent t test (SPSS 22.0) after application of normality test (Shapiro-Wilk). RESULTS: In the analysis of normalized electromyographic data, it was found that the obese group had lower myoelectric activity in protrusion for right masseter and in maximum voluntary contraction with parafilm for right masseter and left masseter ($p<0.05$). The thickness of right masseter was greater for obese group in rest as well as the thickness of right masseter and left masseter in maximum voluntary contraction ($p<0.05$). CONCLUSION:

We can conclude that obesity promotes alterations in stomatognathic system function, especially those related to electromyographic activity and thickness of masticatory muscles. ACKNOWLEDGEMENT: FAPESP (2019/10352-8) and National Institute and Technology - Translational Medicine (INCT.TM).

P2-E-16 Acute exercise effects on response to spinal paired associative stimulation

Jayd Savage[1], Eduardo Toledo-Aldana[1], Cameron Mang[1]
[1]University of Regina

BACKGROUND AND AIM: Previous work reported a facilitatory effect of acute aerobic exercise on excitatory neuroplasticity induced by paired associative stimulation (PAS). Specifically, the effect of PAS targeting motor cortex circuits projecting to the upper limbs was facilitated by a bout of leg cycling. Whether acute exercise effects on neuroplasticity also occur in the spinal cord is not known. The aim of this study was to evaluate whether response to spinal PAS is enhanced by acute exercise. We hypothesized that increases in spinal cord excitability induced by a spinal PAS protocol would be facilitated when preceded by a bout of aerobic exercise relative to a period of rest. METHODS: Twelve young healthy adults underwent a PAS procedure that targets spinal cord circuits projecting to the soleus muscle of the dominant leg on two separate days. In the sessions, PAS was conducted after 25 minutes of seated rest (control) or moderate-intensity arm cycling (rating of perceived exertion of 12-14/20 or 'somewhat hard'). Assessments of spinal and corticospinal excitability were conducted at baseline (i.e., before rest or exercise), and immediately pre- and post-PAS. Measurements of spinal excitability included the stimulus intensity required to elicit the maximal H-reflex (SI-Hmax) and the maximal H-reflex to maximal M-wave ratio (Hmax:Mmax) in the soleus muscle of the dominant leg. Corticospinal excitability was assessed by the amplitude of soleus motor evoked potentials elicited by transcranial magnetic stimulation delivered at 120% of resting motor threshold. Separate two-way repeated measures ANOVAs with factors 'Session' (rest, exercise) and 'Time' (baseline, pre-PAS, post-PAS) were conducted for each dependent variable. RESULTS: With SI-Hmax as the dependent variable, there were no main effects of session ($F(1,11) = .07$, $p = .80$) or time ($F(2,22) = 1.45$, $p = .26$) and no session by time interaction ($F(2,22) = 2.30$, $p = .12$). Considering Hmax:Mmax, the ANOVA did not detect a main effect of time ($F(2,22) = .15$, $p = .86$), or session ($F(1,11) = 1.5$, $p = .24$). However, there was a significant session by time interaction ($F(2,22) = 3.78$, $p = .04$). Post-hoc pairwise t-tests indicated a significant decrease from baseline to post measurements in the exercise session only ($t(11) = 3.13$, $p = .009$). Lastly, with MEP amplitude as the dependent variable, the ANOVA did not detect a main effect of session ($F(1,11) = 1.72$, $p = .22$), but there was a significant main effect of time ($F(2,22) = 7.92$, $p = .003$), such that MEP amplitude appeared to increase similarly over time in both sessions. CONCLUSIONS: The results suggest that arm cycling decreased spinal excitability and may have promoted an inhibitory effect of spinal PAS on spinal excitability. Yet, increases in MEP amplitude in both sessions suggest that there was a supra-spinal increase in excitability that outweighed any exercise-induced decrease in spinal excitability.

P2-E-17 Contributions of intermuscular coherence to balance in persons with Parkinson?s disease

Rowan Smart[1], Owen Harris[1], Anis Toumi[1], Jennifer Jakobi[1]
[1]University of British Columbia Okanagan

Persons with Parkinson's disease (PD) have greater postural sway that non-Parkinsonians. Sway increases from bipedal (BP) to single-leg stance and when standing on foam, and in non-Parkinsonians

intermuscular coherence also increases from BP to single-leg stance and contributes to greater sway. The contribution of lower-leg intermuscular coherence to increased sway in persons with PD is unknown. Nine persons with PD (70±5 yrs, 6 females, UPDRS motor score: 12±6) and 8 age- and sex-matched non-PD controls performed balance tasks of BP and single-leg stance (more affected side in persons with PD) on a force plate with conditions of no foam and standing on 4-inch foam. Participants balanced as long as they could up to 60-seconds. Surface electromyography (EMG) was recorded from medial (MG) and lateral (LG) gastrocnemii, soleus (SOL) and tibialis anterior (TA). Sway parameters and EMG activation were analyzed for the duration of the trials. EMG intermuscular coherence was analyzed between agonist-agonist (MG-SOL, MG-LG, SOL-LG) and agonist-antagonist (MG-TA, SOL-TA, LG-TA) muscle pairs in the alpha (8-13 Hz) and beta (15-35 Hz) frequency bands. Contributions of coherence to sway parameters were assessed using linear regressions. Center of pressure standard deviation in the medio-lateral direction (CoP SD ML) was 73% greater in single-leg compared to BP stance ($p<0.001$), and greater in PD during BP (36%) and single-leg stance (19%) ($p=0.004$). Time-normalized sway area was 169% greater in single-leg compared to BP stance ($p=0.004$), and was greater in PD during BP (43%) and single-leg stance (116%) ($p=0.05$). The foam condition did not alter sway parameters in either group. EMG was greater in single-leg compared to BP for all muscles ($p<0.001$), and was greater in PD compared to controls for MG (77%), LG (76%) and TA (92%) ($p<0.05$), but not SOL ($p=0.99$). Coherence was greater in single-leg compared to BP stance for agonist-agonist alpha (38%,$p=0.03$), agonist-antagonist alpha (47%,$p=0.005$), and agonist-agonist beta (41%,$p=0.002$), while agonist-antagonist beta did not differ between stances ($p>0.05$). Higher agonist-agonist alpha ($R^2=0.41$) and agonist-antagonist alpha ($R^2=0.47$) coherence predicted increased single-leg time-normalized sway area in PD ($p<0.01$). Higher agonist-agonist beta coherence predicted increased time-normalized sway area for PD during BP ($R^2=0.24$) and single-leg stance ($R^2=0.61$) ($p<0.001$), and increased CoP SD ML during single-leg stance ($R^2=0.43$,$p=0.006$). In single-leg stance higher agonist-antagonist beta coherence predicted increased time-normalized sway area in PD ($R^2=0.69$,$p<0.001$) and controls ($R^2=0.32$,$p=0.02$), and increased CoP SD ML in PD ($R^2=0.41$,$p=0.008$). Persons with PD had greater sway than controls, and required more muscle activation to perform the tasks. Intermuscular coherence was a greater predictor of increased sway for persons with PD.

P2-E-18 Muscle Fiber Conduction Velocity of the Quadriceps Vastus Medialis Oblique After an Anterior Cruciate Ligament Reconstruction.

Fernando Lira[1], Ignacio Barra[1]
[1]*Universidad Mayor*

BACKGROUND AND AIM: Knee functional stability after an anterior cruciate ligament reconstruction (ACLR) is the main goal of the rehabilitation process. To achieve this, the normalization of quadriceps muscle (QM) force is crucial. However, after several months of rehabilitation, persistent muscle weakness can be observed. Persistent muscle weakness has been associated with central nervous system reorganization, particularly with α-motoneuron excitability and motor unit recruitment. The assessment of muscle fiber conduction velocity (MFCV) provides information about neuromuscular function and central nervous system organization. Therefore, the aim was to determine the MFCV of the Vastus Medialis Obliquus (VMO) in subjects who underwent an ACLR and compare these values with a healthy control group. METHODS: A total of 36 male subjects participated in this study: 18 healthy participants and 18 operated patients (ACLR group). Participants performed a 10 minute warm up and the quadriceps maximal voluntary isometric contraction (MVIC) was assessed, after this patients were requested to exert a sustained contraction during 30s at 30% of their MVIC, muscle fiber conduction velocity (MFCV) of the VMO was assess using multichannel array electromyography RESULTS: Mean CV was 3.24 ± 1.20 and 4.58 ± 1.21 m/s for the ACLR and Control groups, respectively. The statistical analysis showed a significant difference between groups ($p = 0.0012$). CONCLUSIONS: MFCV has been target as size principle parameter, thus the results of this study suggest that after an ACLR there is an alteration of motor unit recruitment. Nevertheless, it is not possible to stablish the relative contribution of spinal and corticospinal mechanism.

G - Fatigue

P2-G-19 Muscle fatigue indicator in complexe tasks

Marianne Boyer[1], Laurent Bouyer[1], Jean-Sebastien Roy[1], Alexandre Campeau-Lecours[1]
[1]Laval University

BACKGROUND AND AIM : Despite prevention efforts, the prevalence of work-related upper extremity musculoskeletal disorders (WRUED) is increasing. A limit in the development of preventive interventions is the lack of devices that can measure and process sEMG signals in order to provide real-time reliable information on muscular fatigue of the upper limb in relation to the physical demands of the work. Metrics such as median frequency (MDF) and mean frequency (MNF) of the sEMG power spectrum density (PSD) are commonly used as early indicators of neuromuscular changes associated with muscle fatigue. Indeed, these metrics should decrease as the muscle gets tired due to the reduction of muscle fibre conduction velocity. Although the subject has been covered extensively in the past, little research has been done for complex tasks (in different elevation angles and planes). However, in order to serve as a preventive measure, the device must take into account different angles and elevation planes. The objective is to verify if the initial (at the beginning of the task) median frequency of the medial deltoid's sEMG signal depends on 1) the arm elevation angle and 2) the arm elevation plane. METHODS : To do so, a muscle fatigue detection algorithm based on the sEMG signal has been developed. The proposed algorithm uses the median frequency of sEMG power spectrum density (PSD) obtained with the Continuous Wavelet Transform (CWT) as an indicator of the muscle fatigue level. To determine the effect of the elevation angle and elevation plane on the muscle fatigue indicator, four healthy adults performed simple static shoulder tasks in four different orientations (i.e. abduction at 90º, scaption at 90º, flexion at 90º and abduction at 45º). Each subject performed all tasks two times in order to verify the repeatability. RESULTS : It was shown that the initial muscle fatigue indicator is dependent of both the elevation angle and elevation plane. More precisely, the output was at its peak for the abduction at 90º and decreased for the lowest elevation angle. It also decreased as the elevation plane went from side to front. Furthermore, it was also shown that the initial median frequency variation (from tasks to tasks) is also highly subject dependent. For example, subject #2 presented an average gap of 31Hz between the abduction and flexion at 90º. The same subject produced an average gap of 14Hz between the abduction at 90º and 45°. On the contrary, subject #3 presented almost no variation in all tasks. CONCLUSIONS : Since the variations in the initial fatigue indicator is subject dependent, the next step will be to developpe a calibration and modify the algorithm in order to adjust the fatigue indicator according to the current elevation angle and plane. This will make it possible to obtain a fatigue indicator independent of the arm orientation.

P2-G-20 The effect of fatigue on the central activation ratio in young and older adult men

Rami Hammad[1], Vincent Marcangeli[2], Jordan Granet[1], Marina Cefis[1], Justine Lai[1], Pierrette Gaudreau[3],

Richard Robitaille[3], José A. Morais[4], Gilles Gouspillou[2], Mylène Aubertin-Leheudre[1], Marc Bélanger[1]
[1]UQAM, [2]UQAM - Département des sciences biologiques, [3]Université de Montréal, [4]McGill University

BACKGROUND & AIM: Aging is associated with a progressive loss of muscle mass and force. Amongst the main factors related to muscle function decline, there is the capacity to activate the muscle which is often referred to central activation ratio (CAR). More importantly, physical fatigue might alter the CAR leading to a decrease in maximal force (Fmax) that can be generated. Thus, the aim of the present study is to assess the central activation ratio in young and elderly healthy men during maximal voluntary isometric contraction and during fatigue test. METHODS: Twenty-five young (Y: Age=24.6±3.0y; Ht=1.77±0.05m; Wt=81.4±20.1kg), and 20 old (O: Age=74.5±8.7y; Ht=1.70±0.05m; Wt=78.4±8.6kg) men had to do 3-2s maximal voluntary isometric contraction (MVC) of the right knee extensors (hip:90°; knee:135°) followed by a fatigue test (FT). The latter consisted of a series of 2s MVC alternated with 1s rest until Fmax 50% of the initial value was reached. Muscle twitches were produced using a train of 3 to 5-1ms electrical pulses during the MVC and every 30s throughout the FT. Statistical significance was set at $p<0.05$. RESULTS: Young individuals were nearly twice as strong as the elderly participants (Y: 533.78 ±154.1N vs O: 320.23±60.86N). However, the CAR (normalized as % of Fmax) was similar in both groups (Y: 94.5±3.6% vs O: 95.8±3.2%) during the MVC. There was a significant correlation between CAR and Fmax for the young ($r=0.53$) but not in the old ($r=0.27$) participants. However, the difference between the groups was not significant. Fatigue did not alter the CAR in either group with a slope nearly at zero (Y: $0.023x+95.05$; $r^2=0.053$ vs O: $-0.001x+96.21$; $r^2=0.0001$). CONCLUSIONS: The capacity to activate the knee extensors was similar for the young and old individuals during a maximal voluntary isometric contraction and it was not affected by fatigue in either group. The central activation ratio was poorly correlated with maximal force in both groups. Based on these results, it can be inferred that the decrease in force in healthy older adults is not due to alterations in central activation capacity and therefore is associated with other mechanisms. FUNDING: CIHR, RQRV, FRQS (MAL, GG), CFI (MAL), GRAPA.

P2-G-21 Ankle muscle fatigue as a similar effect on static postural control and H-reflex modulation in young healthy males and females.

Donguk Jo[1], Martin Bilodeau[1]
[1]University of Ottawa

BACKGROUND AND AIM: Fatigue-induced changes in postural control can differ between healthy young males and females. A potential contributor to explain such differences could be a sex-related difference in co-contraction of ankle plantar- and dorsi-flexors and/or the modulation of proprioceptive input from ankle muscles, but this has only been sparsely studied. The main aims of the present study were: 1) to determine sex differences in postural control changes with ankle muscle fatigue during a standing forward leaning (FL) task, and 2) to examine whether fatigue affects co-contraction and spinal proprioceptive inputs (assessed through the soleus H-reflex) at the ankle differently according to sex. METHODS: Fifteen healthy young adult males (mean age: 28.0 years) and sixteen healthy young adult females (mean age: 26.1 years) were asked to perform four consecutive FL tasks (30 s; two with eyes open (EO) and two with eyes closed (EC)) before and immediately following a fatiguing exercise consisting of alternating ankle plantarflexion (6 s) and dorsiflexion (2 s) maximal isometric contractions, and at 5 and 10 min of recovery. Center of pressure (COP) sway variables (mean position, standard deviation, ellipse area and average velocity) and an ankle co-contraction index calculated from the root-mean-square (RMS) amplitude of electromyographic (EMG) recordings of soleus, gastrocnemius lateralis

and tibialis anterior muscles, were obtained during one of each pair of FL tasks (2 FL-EOs or 2 FL-ECs). Soleus H-reflex and the maximum amplitude of the compound muscle action potential (Mmax) were obtained during the other FL task of each pair. A rating of perceived exertion was also documented at the different time points. Mixed-model analyses of variance (ANOVAs) were used to assess the effect of sex, fatigue and their interaction on all COP variables, co-contraction index and H/Mmax ratio.RESULTS: Similar effects of ankle muscle fatigue on postural control were found between males and females regardless of vision condition, where both sex groups showed significant increases ($p<0.05$) in mean COP sway velocity with no significant changes in co-contraction indexes. No significant effects of fatigue and related interactions were found for soleus H/Mmax ratio. CONCLUSIONS: Our study showed no significant differences in fatigue-induced postural control changes between males and females following an alternative plantarflexion-dorsiflexion exercise. This could be explained by a similar extent of muscle fatigue between males and females, and also, no changes in co-contraction or modulation of soleus spinal proprioceptive with fatigue for either sex group.

P2-G-22 SEX-SPECIFIC EFFECTS OF FATIGUE ON INTER-JOINT COORDINATION DURING A REPETITIVE POINTING TASK

Chen Yang[1], Yiyang Chen[1], Julie Côté[1]
[1]*McGill University*

BACKGROUND AND AIM: The previous literature has described kinematic adaptations to muscle fatigue during multi-joint movements in which more than two joints were involved to generate the desired movement, showing that the contributions of these joints may vary with fatigue. However advanced tools such as Principal component analysis (PCA) could provide more detailed information about the temporal aspects of entire kinematic waveforms, and how they adapt to muscle fatigue. Besides, sex differences have been detected in the multijoint adaptations to muscle fatigue. However, whether inter-joint coordination adaptations to fatigue varied between sexes remain unclear. METHODS: Eighty-one (41 females) healthy young adults performed a repetitive pointing task (RPT) with the arm moving in a horizontal plane between two targets placed at shoulder height at a constant 1Hz frequency. The task was terminated when neck/shoulder perceived exertion reached 8/10 on the Borg CR10 scale. The first and last 30 seconds during the task were recognized as the non-fatigued (NF) and fatigue-terminal (FT) trials, respectively. Upper body joint angles were recorded using an 8-camera VICON motion capture system. Trunk, shoulder, and elbow angles were used for PCA. The variance of the movement pattern was calculated, and the contribution of each joint angle was described by a weighting coefficient. The effects of fatigue and sex on variances and weighting coefficients were compared using two-way repeated measured ANOVA. RESULTS: There were significant sex*fatigue interaction effects on the weighting coefficients of multiple joint angles. After fatigue, males exhibited greater weightings of shoulder rotation ($p=0.035$) and trunk flexion ($p=0.001$), while females exhibited greater shoulder plane of elevation angle ($p=0.011$) in the fatigued movement pattern. However, the above sex differences did not exist before fatigue. Before fatigue, shoulder elevation ($p=0.034$) and trunk lateral flexion ($p=0.001$) angles weighted more in females' movement pattern, while elbow flexion ($p=0.04$) weighted more in males' movement pattern. However, these sex differences disappeared after fatigue. Besides, a main effect of fatigue showed that fatigue led to decreased weighting of all seven joint angles in principal component. CONCLUSIONS: Taken together, results indicate that before fatigue, movements on the frontal plane weighted more in the movement pattern in females than males. After fatigue, movements on the sagittal plane weighted more in males than in females. The sex differences might suggest

different potential fatigue-related injury risks in females and males. Yang et al., 2018. J Biomech. 76: 212-219. Bouffard et al., 2018. Biol Sex Differ. 9 (1): 1-11.

H – Modelling and Signal Processing

P2-H-24 Artefact detection and elimination in high density surface electromyograms by independent component analysis and activity index

Aljaz Francic[1], Ales Holobar[1], Milan Zorman[1]
[1]University of Maribor, Faculty of Electrical Engineering and Computer Science

BACKGROUND AND AIM: High density surface electromyograms (HDEMG) may contain artefacts that originate from inadequate skin-electrode contact, electrode drift and movement, for example, and may hinder motor unit (MU) identification [2]. Herein we present the methodology for their detection and elimination based on previously introduced independent component analysis (ICA) [1] and activity index (AI) [2]. METHODS: 15-20 second long HDEMG recordings of isometric contractions of the biceps brachii at 5-20 % of maximum voluntary contraction - MVC (13 × 5 electrodes, 7 participants), 10-70 % of MVC (10 × 9 electrodes, 6 participants), tibialis anterior at 5-20 % of MVC (13 × 5 electrodes, 11 participants) and 10-70 % of MVC (10 × 9 electrodes, 9 participants) were analyzed. To detect the artefacts that get projected into the MU spike trains in HDEMG decomposition [2], AI with extension factor set to 1 was calculated from HDEMG [2]. Outliers in AI were detected using the Hampel identifier [3], with window size set to 1 second and sigma parameter, the number of standard deviations, by which a sample of AI must differ from the local median to be identified as an outlier, set to 10, 13, 15 and 20, respectively. FastICA [1] was used to estimate the independent components of HDEMGs. For each identified outlier in the AI, the component containing the artefact was identified by temporarily excluding individual independent components and calculating new AI from the remaining components at the time of the outlier. An interest metric [4], defined as 1 - (new AI)/(old AI) at the time of the maximal outlier peak in the old AI, was calculated for each excluded component. The component with the largest interest metric above the selected threshold of 0.5 was permanently excluded and cleaned HDEMGs were reconstructed from the remaining components. RESULTS: With sigma set to 13 and interest threshold to 0.5, we identified 1.0 ± 2.4 outliers and eliminated 0.8 ± 1.5 artefacts per HDEMG recording. The eliminated artefacts had the interest metric of 0.85 ± 0.09. Lowering sigma to 10 yielded 1.9 ± 4.1 outliers and 1.2 ± 2.0 artefacts but decreased the interest metric to 0.80 ± 0.11. Increasing sigma to 20 decreased the number of outliers to 0.5 ± 1.2 and the number of artefacts to 0.4 ± 1.0 but increased their interest metric to 0.88 ± 0.10. CONCLUSIONS: The proposed technique supports cleaning HDEMG signals prior to identification of individual MUs from HDEMG. By operating on the AI, it focuses on the artefacts that get projected into the MU spike trains during HDEMG decomposition [2]. Its sensitivity to artefacts may be controlled by finetuning the sigma and the interest threshold parameters. ACKNOWLEDGEMENT: This study was supported by the Slovenian Research Agency (Project J2-1731 and Program funding P2-0041). [1] Independent component analysis: algorithms and applications. Hyvärinen, 2000. [2] Multichannel blind source separation using convolution kernel compensation. Holobar, 2007. [3] The identification of multiple outliers. Davies, 1993. [4] On artefact elimination in high density electromyograms by Independent Component Analysis. Frančič, 2021. [Figure 1]

P2-H-25 Identifying the postural control system for quiet standing in individuals with spinal cord injury

Jae Lee[1], Katherine Chan[2], Janelle Unger[3], Kristin Musselman[4], Kei Masani[2]

[1]Institute of Biomedical Engineering, University of Toronto, [2]KITE-Toronto Rehabilitation Institute, [3]Western University, [4]University of Toronto

BACKGROUND AND AIM: Static posturography, which quantifies body sway during quiet standing, is a popular method for assessing balance impairment. However, this method does not necessarily represent one's postural control system. Instead, parametric system identification is a more direct method to quantify one's postural control system. We previously proposed a novel parametric system identification method using data from unperturbed standing and theoretically validated this method through computational simulations. Here we investigated the differences in postural control system between able-bodied (AB) individuals and those with incomplete spinal cord injury (iSCI) during standing. METHODS: We used cascaded linear controller and single-link inverted pendulum model as the postural control system. The ankle torque consists of active and passive torque. The active ankle torque is generated through neural controller, represented by a proportional-derivative (PD) controller, followed by the neuromuscular system (NMS), represented by the critically damped second-order system, that converts the neural controller output to the active ankle torque. The passive torque is generated through ankle stiffness and is represented by another PD controller. We apply two optimization steps. In step 1, the soleus (SOL) electromyography (EMG) data and the angle of the inverted pendulum model are used as inputs to the NMS and the passive PD controller, respectively. The output, which represents ankle torque, is fitted to the experimental ankle torque via optimization. This step identifies NMS system (muscle twitch contraction period) and passive PD controller. In step 2, the angle of the inverted pendulum is used as an input to the neural controller and passive controller. The output is fitted to the experimental ankle torque to identify neural controller. For this study, data from 21 individuals with iSCI and 14 age- and sex-matched AB individuals were used. The participants performed a 150-s quiet standing tasks. We performed the system identification for each individual and compared the identified controller parameters between AB individuals and those with iSCI. RESULTS: As our iSCI participants showed relatively high ability in standing, we selected 5 participants with iSCI who showed considerably larger sway compared to the AB participants and selected corresponding age-matched AB participants' data. We found that the ankle stiffness was significantly smaller for those with iSCI than for AB individuals ($p=0.019$). The proportional gain of the neural controller was not significantly different but showed increasing trend for those with iSCI ($p=0.053$). CONCLUSION: These preliminary results shows that the ankle stiffness was reduced following iSCI, indicating that these individuals demonstrated greater active torque during quiet standing, resulting in reduced postural stability due to large sensorimotor delays included for active ankle torque generation process.

I – Motor Control and Motor Learning

P2-I-26 Breaking Barriers to Designing Online Experiments: A Novel Open-Source Platform for Supporting Procedural Skill Learning Experiments

Luis Cubillos[1], Thomas Augenstein[2], Rajiv Ranganathan[3], Chandramouli Krishnan[2]
[1]NeuRRo Lab, [2]University of Michigan, [3]Michigan State University

BACKGROUND AND AIM: Motor learning experiments are typically performed in lab environments under the close supervision of a researcher. However, conducting in-person experiments requires dedicated equipment/personnel and impedes the ability to perform experiments with adequate sample sizes, especially in this pandemic. To address this issue, some researchers have transitioned to unsupervised online experiments, showing significant advantages in participant recruitment while still achieving similar results to in-person experiments. However, existing online platforms require coding experience or time-consuming setups to create and conduct experiments, limiting their usage across the field. This study presents and validates a web-based platform that allows researchers to design, set up, run, and manage a commonly used procedural skill learning experiment without the need for any coding experience. METHODS: We first developed an online platform to conduct a procedural skill learning experiment using Django 3.1 and Vue 3.0 web frameworks. We then performed a validation experiment in 41 right-hand dominant young adults (Supervised = 17; Unsupervised = 24) to determine if the results of supervised and unsupervised (i.e., online) experiments are similar. The experiment consisted of two parts. The first part was a replication of a previous study, where participants learned to type the sequence 41234 as fast and as accurately as possible with their left hand. The second part was an interlimb transfer study where the participants learned to type the sequence 70897 as fast and as accurately as possible with their right hand. Participants received 36 blocks of training for each hand with each block consisting of 10 s of practice and 10 s of rest. We computed speed in taps per second for each trial within the block. Performance improvements were quantified by computing the improvements in tapping speed with practice. We also computed micro-scale learning to quantify performance improvements occurring during practice (micro-online) and during rest (micro-offline) periods. Improvements in performance and interlimb transfer were tested for significance using one-sample t-tests. Learning between the supervised and unsupervised training was compared using two-sample t-tests. All p-values were adjusted for multiple comparisons using the Benjamin-Hochberg procedure. Non-significant results between groups were tested for equivalence using two one-sided tests (TOST) for equivalence procedure. RESULTS: No differences in learning between the supervised and unsupervised groups were observed across all variables (all p's > 0.05). The learning curves and average tapping speeds were also similar to prior studies. There were significant improvements in mean tapping speed with training (2.22 ± 0.23 taps/s, $p<0.001$). There was also a significant interlimb transfer of learning (1.22 ± 0.22 taps/s, $p<0.05$). CONCLUSIONS: Our results show that the presented platform is a valid tool to conduct online procedural skill experiments. Furthermore, the platform's open-source nature will allow the community to determine and develop other relevant features as the need for them arises.

P2-I-27 Gymnastics experience modulates default response of inter-limb reflex during postural maintenance by upper limbs

Hirotaka Sugino[1], Junichi Ushiyama[1]
[1]*Keio University*

BACKGROUND AND AIM: We usually coordinate our upper limbs to perform various types of movements such as carrying a dish tray and steering a car. Coordinated control of both arms is also observed in involuntary reflex responses, called "inter-limb reflex". When a mechanical perturbation is applied to one arm during the task in which participants control a virtual tray with both arms, a long-latency reflex is known to be occurred in both arms. In contrast, such inter-limb reflex does not appear when separate task demands are given to both arms. In addition, it has been well studied that in athletes, prolonged sports training modulates the default response of reflexes to acquire the sports-specific manipulation of their bodily movements. However, although sports-specific bimanual coordination should be required for athletes, no studies have reported sports-specific modulation of inter-limb reflexes in athletes. To examine it, we used gymnasts as participants, who have spent many years from childhood to acquire specialized skills to control their balance by using only their upper limbs, such as hand standing. We hypothesized that gymnasts' inter-limb reflex of the upper limbs is specifically modulated to control

their posture using upper limbs. METHODS: Nine gymnasts and nine normal healthy adults as controls were participated. The participants manipulated the two cursors indicating the position of each hand to maintain starting positions against a background load that flexed elbow joint by using robot manipulandum (KINARM). Then, a mechanical perturbation to flex the elbow joint on one side was given at random timing, and participants moved the cursor back to the starting position as soon as possible. The stretch reflex was measured from the surface electromyogram signals recorded from the triceps brachii muscle of both arms. RESULTS: Although each arm respectively controlled independent cursor, when the dominant hand was perturbed, both arms showed reflex responses with a long-latency component in the gymnasts. In the controls, only the perturbed arm showed a stretch reflex. (Fig. A). On the other hand, when the non-dominant hand was perturbed, the same reflex response was observed on perturbed side (non-dominant hand), but not on the unperturbed side (dominant hand) in both groups. (Fig. B). CONCLUSIONS: Our findings provide the first demonstration of modulation of inter-limb reflexes by sports experience. The results suggest that prolonged training modulates the default response of the inter-limb reflex to a perturbation to one arm driving a reflex response in both arms. This response is consistent with lower limb, which works to maintain posture by extending the contralateral limb when one limb is flexed. Gymnasts' high level posture maintenance by the upper limbs could be supported by this reflex response. In addition, reflex responses were observed in both arms only when applying perturbation to the dominant hand, which would reflect that gymnasts' non-dominant hand strongly contributes to postural control in the upper limbs.

P2-I-28 Differential Changes in Short and Middle-latency Somatosensory Evoked Potentials and Motor Performance: Effects of Neck Muscle Vibration on Sensorimotor Integration & Motor Learning

Hailey Tabbert[1], Ushani Ambalavanar[1], Bernadette Murphy[1]
[1]*Ontario Tech University*

BACKGROUND AND AIM: Neck joint dysfunction as a result of pain, fatigue and postural stress impacts motor learning, proprioception, and cortical processing, due to altered afferent input. It is unclear whether transient alterations in neck sensory input from muscle vibration impacts body schema as well neural mechanisms associated with motor learning and sensorimotor integration (SMI), following the acquisition of a proprioceptive based task. The purpose of this research was to determine the effects of neck muscle vibration on SMI and motor learning using somatosensory evoked potentials (SEPs). METHODS: 24 right-handed, healthy participants (11F) aged 22.26±2.6 had right-median nerve stimulation at 2.47Hz and 4.98Hz to elicit short and middle-latency SEPs. 1000 sweeps were recorded and averaged using a 64-lead EEG cap pre- and post-acquisition of a force matching tracking task(FMTT). Following pre-acquisition, controls(n=13,7F) received rest (10min) and vibration(n=11,6F) received 60Hz vibration (10min) on the right sternocleidomastoid and left cervical extensors. Task performance was measured 24 hours later to assess retention. Repeated measures ANOVAs compared SEP amplitudes and performance accuracy normalized to baseline. RESULTS: Time by group interactions occurred for the N18 SEP: increased by 58.74% in controls and decreased by 21.78% in vibration($p=0.02$) and the N24 SEP: decreased by 14.05% in controls and increased by 15.57% in vibration($p=0.03$). Changes in the N11, P25 and N30 peaks were significant over time where the N11 increased by 18% in controls ($p<0.001$) and decreased by 8.59% in vibration($p<0.001$), the P25 increased by 9% in controls($p=0.03$) and by 20.41% in vibration($p=0.03$), and the N30 increased by 7.38% in controls($p=0.04$) and by 11.63% in vibration($p=0.04$) when compared to baseline. Relative to baseline performance, within-group interactions occurred post-acquisition, where controls improved by 12.29%($p<0.001$) and vibration improved by 15.37%($p<0.001$). In retention, controls improved by 12.72%($p<0.001$) and vibration improved by 14.55%($p<0.001$). Post-acquisition to retention, there were no significant changes with controls improving by an additional 0.43% and vibration worsening by 0.82% relative to retention. CONCLUSIONS: Group-dependant changes in SEP peaks associated with cerebellar processing (N18 and N24) were observed following motor acquisition. The N18 represents pathways related to processing of cerebellar inputs while the N24 represents processing in the cerebellum to primary somatosensory cortex pathways. This suggests that vibration altered proprioceptive processing used to construct body schema leading to alterations in cerebellar processing and motor control. Future studies should assess retention at longer intervals to determine if the observed neurophysiological adaptations translate to more profound behavioural changes between groups.

J – Motor Disorders

P2-J-30 Coherence between muscle activations and tremor in the upper limb of persons with essential tremor

Daniel Free[1], Ian Syndergaard[1], Adam Pigg[1], Silvia Muceli[2], Johanna Thompson-Westra[3], Karin Mente[4], Carine Maurer[5], Dietrich Haubenberger[3], Mark Hallet[3], Dario Farina[6], Steven Charles[1]
[1]Brigham Young University, [2]Chalmers University of Technology, [3]National Institute of Neurological Disorders and Stroke, NIH, [4]Case Western Reserve University, [5]Stony Brook University, [6]Imperial College London

BACKGROUND AND AIM: Peripheral suppression techniques are an attractive alternative to essential tremor (ET) patients who may be dissatisfied with front-line treatment options (medication and neurosurgery). However, knowing which muscles or joints to target for suppression requires knowledge of those most responsible for tremor. This identification is not trivial because tremor propagates through multi-articular muscles and limb dynamics. Therefore, tremorogenic activity in one muscle can produce tremor in all degrees of freedom (DOF), often in a non-intuitive manner. The amount of shared content in the pathological tremor band (4-12 Hz) between muscle activations and joint/hand tremor has not been established and may help in identifying which muscles are key tremor generators. Additionally, activations of different muscles are not independent of each other, and the extent to which the shared content is due to supraspinal sources versus afferent feedback is currently unknown. The purpose of this research is to characterize the relationships between muscle activations, between muscle activations and joint displacement, and between muscle activations and hand displacement in the tremor band. METHODS: 24 ET subjects were recruited for this study. They performed both postural and kinetic tasks representative of activities of daily living. Joint angles from the 7 DOF of the shoulder, elbow, and wrist and surface EMG from the 15 major superficial muscles of the upper limb were recorded while subjects performed these tasks. We calculated the coherence (frequency-dependent correlation) at tremor frequencies between muscle activations, between muscle activations and joint displacement, and between muscle activations and hand displacement. The difference in phase between the muscle pairs at the tremor frequency was also calculated. RESULTS: Our findings show a strong pattern that can be roughly characterized by functional relationships between muscle pairs. Muscle pairs often characterized as synergistic, particularly those spatially close to each other, had the highest coherence and were consistently in phase; antagonistic muscle pairs had intermediate coherence values and demonstrated a binary pattern of either in-phase or antiphase with each other; and muscle pairs with less defined functional relationships had the least coherence and inconsistent phase differences.

Coherence between muscle activations and joint DOF was highest among the distal DOF and mostly involved distal muscles. Elbow flexors and wrist extensors tended to share the most content with the movement of the hand. CONCLUSION: This characterization provides preliminary insights into determining which muscles contribute the most to tremor.

P2-J-31 Inter- and intra-individual variability in hand and leg motor cortices excitability in Parkinson's disease and freezing of gait

Alexandra Potvin-Desrochers[1], Alejandra Martinez Moreno[1], Julien Clouette[1], Henri Lajeunesse[1], Freddie Seo[1], Gleydciane Alexandra Fernandes[1], Frédérike Parent-L'Ecuyer[1], Audrey Parent[1], Alexander Fulford[1], Michelle Cheng[1], Caroline Paquette[1]
[1]McGill University

BACKGROUND & AIM Freezing of gait (FOG) is a common motor symptom of PD for which few therapeutic strategies exist. Repetitive transcranial magnetic stimulation (rTMS), a form of non-invasive brain stimulation, is drawing more and more attention for FOG. rTMS has the ability to modulate the cortical excitability of the brain region stimulated, and to improve associated motor symptoms. However, baseline cortical excitability metrics have never been characterized in this population. The purpose of this study was thus to describe hand and leg motor thresholds, and their intra- and inter-individual variability, in people with PD and FOG. METHODS Fifteen individuals with Parkinson's disease and FOG were recruited and took part into four sessions, separated by at least 72 hours, all at the same time of the day, while participants were on their usual medication schedule. The cortical motor representations of the left first dorsal interosseous (FDI) and of the left tibialis anterior (TA) were targeted by TMS and their resulting motor evoked potentials (MEPs) were recorded. Resting motor threshold (RMT) was acquired from the TA and the FDI with, respectively, a 60mm domed coil and a 25-mm figure-of-eight coil connected to a MagStim 2002 stimulator. RMTs were defined as the lowest intensity that evoked ten MEPs of at least 0.05mV out of twenty TMS stimuli in the muscle at rest. Active motor threshold (AMT) was acquired from the FDI using a 50-mm figure-of-eight coil connected to a Magstim Super Rapid 2 stimulator. AMT acquisition followed the same protocol as RMTs, but participants had to maintain their FDI contracted at 20% of their maximal voluntary contraction. Finally, the percentage of maximal stimulator output necessary to generate MEPs of an averaged amplitude of 1mV over ten TMS trials was also determined from the TA. RESULTS Preliminary data was analyzed in ten participants. RMTs for the FDI and the TA were 40% ± 7% (range: 31% to 88%) and TA 50% ± 17% (range: 31% to 85%) respectively. Intraindividual variability of the FDI (mean SD= 3 ± 3) and TA (mean SD= 2 ± 1) RMTs was similar (P=0.3036), but the latter presented significantly more interindividual variability (mean SD= 17) than the FDI (mean SD= 7) RMT (P=0.0001). Mean AMT of the FDI was 38% ± 7% (range: 27% to 50%), and despite the necessity to maintain a voluntary muscle contraction, its intraindividual variability (mean SD= 2 ± 2) was not different from the FDI (mean SD= 3 ± 3) RMT (P=0.2513). The mean stimulator output necessary to reach 1mV responses in the TA was 60% ± 16 (range: 32% to 76%). It was impossible to reach 1mV responses in the TA for two of the participants, and those participants were the ones with the highest TA RMTs (65% and 85%). CONCLUSION Stimulating the cortical motor representation of the TA with TMS is more appropriate than the FDI for gait impairments such as FOG. However, preliminary data seems to show that the latter offer less variability and more feasibility in a population of PD with FOG.

P2-J-32 Reduced rate of torque development during ballistic isometric contraction of plantar flexors in chronic stroke survivors

Jongsang Son[1], William Rymer[2]
[1]Shirley Ryan AbilityLab (formerly Rehabilitation Institute of Chicago), [2]Northwestern University

BACKGROUND AND AIM: The rate of torque development (RTD), often defined as the slope of the torque-time curve during ballistic isometric contraction, has been considered an important feature to characterize muscle contractile function and motor performance. It is well accepted that the early-phase RTD (< 100 ms) is likely associated with neural factors and late-phase RTD (100-200 ms) with muscular factors, respectively. However, this has not been tested for chronic stroke-impaired muscles that are potentially impacted by many changes in both neural and muscular factors. Thus, this study aims to compare RTD between paretic and non-paretic plantar flexors of seven chronic stroke survivors. Ultimately, we seek to understand the potential contributions of neural and muscular factors to RTD after chronic stroke. METHODS: The participants were asked to perform three maximum isometric plantar flexions as fast and hard as possible. RTD was then calculated at multiple time intervals (i.e., 30, 50, 100, and 200 ms) to evaluate whether the RTD measure can detect chronic stroke-related changes in neural and muscular factors. RESULTS: Our preliminary results demonstrated that RTDs at all time intervals were significantly smaller in paretic muscles compared to non-paretic muscles ($p < 0.05$). We propose that the reduced early-phase RTDs (i.e., 30 and 50 ms) may be associated with the reduced neural drive after stroke and that the reduced late-phase RTDs (i.e., 100 and 200 ms) may be attributable to the changes in muscle-tendon properties after stroke. In addition, there was a significant relationship between the relative (paretic / non-paretic) peak torque and relative RTD at 200 ms ($r = 0.893$; $p = 0.012$), supporting the previous assumption that the late-phase RTD may be more closely related to maximal strength. CONCLUSIONS: The findings of this preliminary study indicate that RTD may be a simple measure to represent stroke-related neural and muscular changes. Further studies are required to address the potential contributions of neural and muscular factors to the reduced RTD after chronic stroke.

K – Motor Units

P2-K-33 Estimation of motor unit-specific activation properties in the intact human in vivo

Antonio Gogeascoechea[1], Antonio de Jesus Gogeascoechea Hernandez[2], Massimo Sartori[2]
[1]University of Twente, [2]Universiteit Twente

BACKGROUND AND AIM: The development of neuro-restorative technologies is hindered by our limited understanding of the interaction between neural and mechanical levels of human movement. Current electromyography (EMG)-driven neuro-musculoskeletal models aim at representing such underlying mechanisms of force generation in healthy and neurologically injured individuals. However, as they often employ global EMG, they fail to capture the excitation-contraction coupling in detail. The ability to decode motor neuron activity from high-density EMG enables expanding current generalized neuro-musculoskeletal models into motor unit (MU)-specific formulations. In this context, we propose a high-resolution framework to sample MU statistical distributions, and to use them for generating MU-specific twitch responses. METHODS: A healthy subject performed a series of isometric dorsi-plantar flexion contractions across different levels of activation and ankle positions. Torque measurements were collected and high density-EMGs were recorded from the lower leg muscles. These were in turn decomposed into constituent MU firing events using a de-convolutive blind source separation technique. We first estimated mean discharge rate and recruitment threshold for each decoded spike train. Then, we computed a linear combination of these neural features (Figure 1.A) through principal component analysis and projected the neural features onto the eigenvector. To map the neural features into twitch contractile properties, we computed piecewise linear interpolations between the projected data and twitch contraction times found on humans (Figure 1.B, bottom) using characteristic landmarks of their distributions (e.g. peaks and valleys, Figure 1.B, middle). Finally, we employed the estimated contraction times (Figure 1.C) to design twitch responses for each MU. The total MU-specific activation was defined as the sum of the individual twitch responses per muscle. RESULTS: The probability density functions depicted an overlapping mixture of two populations (Figure 1.B, top). The coefficients of determination (R^2) between the total activation per muscle and the normalized torque were: $R^2>0.85$ for the tibialis anterior and medial gastrocnemius, $R^2>0.8$ for the soleus and peroneus, and $R^2>0.83$ for the lateral gastrocnemius (95% confidence interval). CONCLUSIONS: We proposed a methodology for sampling neural features, mapping them into contractile properties and modelling MU-specific activation profiles. The overlapping mixture of Gaussians may correspond to slow and fast MU populations. The identification of MU contraction times allows designing activation profiles with a high degree of similarity to actual torques across all the recorded muscles ($R^2>0.8$). We expect that this will improve torque predictions across multiple conditions and will open up new avenues for understanding how motor neurons interact with muscles and how they modulate in response to neurorehabilitation devices.

P2-K-34 Estimates of persistent inward currents in the lower limb are larger in females than males.

Sophia Jenz[1], James Beauchamp[1], Matheus Gomes[2], CJ Heckman[1], Gregory Pearcey[1]
[1]Northwestern University, [2]University of São Paulo

BACKGROUND AND AIM: All movement is achieved by activation of motoneurons and the muscle fibers they innervate, collectively known as motor units (MUs). Non-invasive recordings of MU activity provide great value for understanding the properties and behavior of individual motoneurons, and how neural drive is modulated based on varying physiological conditions or motor commands. The effect of biological sex on motoneuron physiology, however, is understudied, and has been for quite some time. Reasons for the exclusion of females in both human and non-human animal studies have stemmed from the assumption that menstrual cycles and sex hormones may introduce additional variability that could interfere with the physiological system being studied. Paradoxically, there are many known sex differences in both neurological impairment and human performance that warrant the study of sex differences in this field of research. To address this disparity, we investigated whether MU behavior differed between sexes. METHODS: We decomposed individual MU spike trains from the tibialis anterior, medial gastrocnemius, and soleus muscles using high-density surface electromyography and blind source separation algorithms. Participants (N = 14, 25.9 ± 5.4 years, 7 female) performed triangular ramp shaped contractions to a peak of 30% maximum during either isometric dorsiflexion or plantarflexion. Instantaneous firing rates of each MU were determined by computing the inverse of the interspike interval. Persistent inward currents (PICs), which provide a proxy for the level of neuromodulatory drive, were estimated using a well-validated paired-MU analysis technique, which quantifies discharge rate hysteresis (ΔF) by obtaining the discharge rate of a lower-threshold MU (reporter unit) at the onset and offset of a higher-threshold MU (test unit). We used linear mixed effects models to determine if ΔF and MU discharge rates were predicted by the fixed effects of sex, muscle, and their interaction. RESULTS: Biological sex was a significant predictor of ΔF ($F_{1, 15.2} = 12.54$, $p = 0.003$), as well as both initial ($F_{1, 15.0} = 6.98$, $p = 0.019$) and peak discharge rate ($F_{1, 17.1} = 4.430$, $p = 0.05$). Across all muscles, ΔF (β=-1.078, SE=0.305), initial discharge rate (β=-0.970, SE=0.367), and peak

discharge rate (β=-1.657, SE=0.787), were substantially larger in females than males (see figure). CONCLUSIONS: These findings suggest that motor commands and/or motoneuron excitability likely differ between the sexes, which may manifest in the MU discharge patterns. This calls for future studies to include equal numbers of female and male participants and for sex to be analyzed as a biological variable.

P2-K-35 Relationship between force fluctuation and motor unit activities in the peroneus muscles

Shun Kunugi[1], Ales Holobar[2], Akane Yoshimura[1], Tetsuya Hirono[1], Kohei Watanabe[1]
[1]Chukyo University, [2]University of Maribor

Background and aim: Motor unit (MU) activities of the peroneus muscles may reveal the cause of weakness and poor force control of the ankle eversion (e.g., in patients with ankle instability) but have not been intensively studied by the means of high-density surface EMG (hdEMG). In this study, we analyzed the relationship between the MU activity and the evertor force fluctuations in isometric ramp & hold contractions. Methods: Thirty-one healthy males (means ± SD; age, 21.6 ± 4.0 yr; height, 170.6 ± 5.7 cm; weight, 64.0 ± 9.9 kg) participated to this study. MU activities were identified from hdEMG (13 × 5 electrodes, interelectrode distance of 8 mm and 4 mm) of the peroneus longus (PL) and brevis (PB) muscles during isometric ankle eversion at 15 % and 30 % of maximal voluntary contraction (MVC). Participants gradually increased contraction level until reaching the target and held it for 15 s. The exerted force was recorded by the Con-Trex-MJ, and displayed as feedback on a monitor, along with the target torque. hdEMG signals were decomposed into individual MUs using DEMUSE software (version 5.0.1). The central 10 s of the hold phase were used for analysis so that MUs recruited before this range were retained for further analysis. A cumulative spike train (CST) was calculated using MU firings identified from both muscles (8.2 ± 5.9 (range 1-25) MUs and 10.1 ± 5.8 (range 1-22) MUs at 15 % and 30 % of MVC, respectively). The variability of the force and CST were represented by the coefficient of variation (CoV). Spearman's rank correlation coefficient was used to assess the relationship between the CoV for force and the CoV for CST. Significance was accepted for p-values less than 0.05. Results: For the 15 and 30% MVC trials, the CoV for force was 3.5 ± 1.9 % and 3.0 ± 1.3 % and the CoV for CST were 6.9 ± 2.8 % and 7.5 ±2.7 %, respectively. Correlation was not significant at the 30 % of MVC (rs = 0.32, p= 0.08), but was significant at the 15 % of MVC (rs = 0.39, p = 0.03). At the 15 % of MVC, there was a significant correlation between force fluctuations and variability of MU activities, but the correlation was not strong. This may be due to the relatively limited number of identified MUs. Additionally, while in the tasks requiring the joint stabilization agonistic and antagonistic muscles are likely coactivated, we were not able to evaluate the activity of antagonist muscles. Conclusion: This study shows that in the peroneus muscles force fluctuation moderately correlate with variability in the activity of noninvasively identified MUs but at 15 % of MVC only. Further studies are required to clarify whether the observed lack of correlation is due to the low number of identified MUs or due to coactivation of antagonistic and agonistic muscles.

P2-K-36 Reliability of volitional muscle activation determination using the interpolated twitch technique in boys and men

James Maynard[1], Nicole Jenicek[1], Raffy Dotan[1], Michael Holmes[1], David Gabriel[1], Bareket Falk[1]
[1]Brock University

Background: Maximal force production largely depends on the ability to activate motor units (MUs). The interpolated twitch technique (ITT) is commonly used to determine the extent (%) of MUs activated during a maximal volitional contraction (MVC). A stimulated twitch is superimposed during MVC (SItw), and a subsequent twitch of the resting muscle (Rtw), are used to estimate volitional MU activation (VA). Early studies reported lower VA in children, while several recent studies suggested no age-related differences. The reliability of VA determination has been studied to a limited extent in adults but has not been examined in children. Purpose: To assess age-related VA difference and ITT reliability in boys and men. Methods: Participants were 11 boys (8–12 years) and 12 men (18–30 years). Following a habituation session, two identical test sessions were conducted in which participants performed 10 x 5-s knee-extension MVCs with 2-min rest intervals. Each contraction was immediately followed by an Rtw. SItw was applied only to the last five MVCs of each series. Force was measured by an isokinetic dynamometer in isometric mode. Age-related VA differences were determined using a repeated measures ANOVA. ITT reliability (SItw, Rtw, VA) was assessed in 7 boys and 12 men, using intraclass correlation coefficients (ICC), derived from a fully nested ANOVA model. Results: Maximal knee extension torque was significantly lower in boys compared with men (84.4±18.5 vs. 267.8±67.6 N.m, respectively), even after correcting for body mass (2.3±0.5 vs. 3.3±0.6 N.m.kg-1, respectively). VA was significantly lower in boys than in men (visit 2: 92.6±4.5 vs. 95.2±2.0 %, respectively; visit 3: 93.5±3.4 vs. 96.2±2.8%, respectively, group effect = 0.04), with no difference between visits nor group-by-visit interaction. A similar pattern was observed for the SItw and Rtw. The ICC for VA was higher in men than in boys (r=0.73 vs. 0.28, respectively). In both groups, most of the inconsistency in VA stemmed from inter-trial variability (58.2% and 59.7% of total variance for boys and men, respectively). The SItw reliability was moderate in both groups (ICC=0.69 and 0.47 for boys and men, respectively). In boys, between-subjects, -days and -trials contributed similarly to the ICC for the SItw (27-39%), while in men, most of the variability stemmed from inter-trial variability (55.3%). The Rtw reliability was high for boys and men (r = 0.96 and 0.85, respectively), with most of the variability observed between subjects (90.5 and 72.1%, respectively). Conclusions: In congruence with previous findings, boys' knee extensors VA was lower than that of the men. Contradictory reports of age-related differences in VA in the literature may be due to lack of reliability, and specifically, lack of trial-to-trial consistency using the ITT.

P2-K-37 Neural control of the motor units innervating the extrinsic muscles of the hand during individual and combined digit movements at different speeds

Marius Oßwald[1], Andre Cakici[1], Daniela Souza De Oliviera[1], Alessandro Del Vecchio[1]
[1]*Friedrich-Alexander-Universität Erlangen-Nürnberg*

The human hand shows a large number of degrees of freedom. Hand dexterity is encoded by the discharge times of spinal motor units (MUs). Most of our knowledge on the neural control of movement is based on the discharge times of MUs during isometric contractions. Here we designed a noninvasive framework to study spinal motor neurons during dynamic hand movements with the aim to understand the neural control of MUs during sinusoidal hand digit flexion and extension, and different grasping and pinching motions at different rates of force development. The framework included acquisition of high-density surface EMG data from 320 electrodes placed on the extrinsic hand muscles on the forearm, with markerless generation of 3D hand kinematics extracted with deep learning, and a realistic virtual hand that displayed the motor tasks for comparability across subjects that was synchronized with the EMG and digital camera signals. The dataset was acquired from 13 healthy subjects performing 13 movement tasks including 14 degrees of freedom. The movements included flexion and extension of individual hand digits at two different speeds (0.5 Hz and 1.5 Hz) and different pinching and grasping motions for 40 seconds. Through a semi-automatic blind source separation approach, we found on average 4.7 ± 1.7 MUs across participants and tasks. Most MUs showed a biphasic pattern closely mirroring the flexion and extension kinematics of the digit tips. Indeed, a factor analysis method (non-negative matrix factorization) was able to learn the two components (flexion/extension) with high accuracy at the individual MU level ($R = 0.87 \pm 0.12$). Although most MUs were highly correlated with either flexion or extension movements, there was a smaller proportion of MUs that showed no modulation in firing activity with the task-specific movement and was therefore controlled by a different neural module (7.1% of all MUs with $R < 0.3$). This work shows a noninvasive visually guided framework to study motor neurons controlling the movement of the hand in human participants during dynamic hand and digit movements via accurate markerless acquisition of 3D hand kinematics and synchronized muscle activity from high-density surface EMG signals.

L - Muscle Synergy

P2-L-38 Predicting 3D reaching direction through synchronous muscle synergies

Simone Ranaldi[1], Cristiano De Marchis[1], Silvia Conforto[1]
[1]*University Roma TRE*

BACKGROUND AND AIM: Predicting upper limb reaching direction during unconstrained movements through sEMG signals is a widely investigated challenge in the field of intuitive and interactive myocontrol of prosthetic and rehabilitation devices. Current state of the art methods are characterized by a relatively low reliability and require complex and time-consuming training routines that often affect the use of such technologies in everyday life. As a potential means for improving the performance myocontrol algorithm, the theory of synchronous muscle synergies might represent a valuable feature extraction tool for the processing of multi-muscle sEMG signals. METHODS: In this work, data from 9 muscles of the dominant arm of 8 healthy subjects have been acquired during a free reaching task. Reaching targets were placed in three groups of 5 directions in the transverse plane, at three different heights, yielding a total of 15 different directions. The whole set of targets has been reached 10 times by each subject. Four synergies were consistently identified through the whole population, reflecting anatomical and functional organization of the arm muscles. The investigation about the direction discrimination has been carried out by analysing the magnitude of the activation of each synergy during each reaching movement. RESULTS: Results have qualitatively shown that across the analysed reaching directions two out of the four identified synergies carry the most predictive information. In detail, the synergy composed of elbow flexors have higher activation levels when reaching higher heights, while the deltoids synergy show higher levels of activations for higher targets as well as for targets that are farther from the center of the body. The other two synergies, including one mostly the pectoralis and the other the triceps and some additional deltoid activity, share a mostly consistent activity across the different subjects but seem to carry no information about these particular reaching targets. DISCUSSIONS: These preliminary results show that synergy analysis might represent a valuable physiologically inspired feature extractor for predicting reaching directions in an unconstrained scenario. While this has already been proven in the literature for reaching fixed targets, participants in this study were only given approximate information on target positioning, with no visual clue or information, so that the true reaching position was characterized by an high degree of variability. These particular aspects of the experimental protocol suggest that the results presented here might be representative of

everyday life scenarios, in which no constrained are placed on the relative position between the body and the target of the reaching movement.

P2-L-39 The analysis of the muscle synergies during an incremental pedaling exercise

Kengo Wakui[1], Yukihiko Ushiyama[1], Shuhei Kamyama[2], Kazuto Kamitaira[3]
[1]Niigata University, [2]Niigata University of Management / Niigata University, [3]Graduate School of Modern Society and Culture, Niigata University

BACKGROUND AND AIM: It is said that the increasing rate of EMG is not consistent during an incremental exercise. In the graph plotted RMS of these muscles' EMG, the break point where the slope become steep is observed and it's called EMG threshold (EMGT). Previous studies describe that the cause of non-linear EMG increase despite of linear increase of workload is the accumulation of lactic acid in muscles. Though, before the beginning of accumulation, additional motor units are recruited just in response to increasing workload, after that, each motor unit's contractive force decrease because of lactic acid and more additional recruitment of motor units as compensation for it is needed. Then, previous studies showed that the EMGT was observed primarily in knee extensor muscles. In other words, some muscles indicated EMGT, other muscles did not. Regarding them, we hypothesized that different motor control patterns are observed during an incremental exercise. In present study, we investigated the changes of muscle synergies using EMG obtained at each workload during an incremental exercise. METHODS: Male cyclists performed 10 minutes incremental pedaling exercise (90rpm, start at 110W, +10W every 30 seconds) and EMG measured from 9 lower limb muscles. At the same time, the acceleration and angular velocity of crank was measured to synchronize the EMG data and crank motion. The ARV was calculated from filtered EMG and divided into each workload. Then, averaged ARV was calculated from steady 5 ~ 10 cycle data at each workload, and they are normalized to the maximum value for that muscle over all workloads. By using non-negative matrix factorization (NMF), muscle synergies were extracted from each participant. To evaluate differences between sets of muscle synergies among different workloads, we performed EMG reconstruction analysis and hierarchical clustering. The optical number of clusters was determined by the gap static method. RESULTS: As a result of hierarchical clustering to each participant, some reconstructed EMG accuracy vectors were divided into two or three clusters. They are generally sorted by each band of workload (low - high, low - middle - high), and the structures of the clusters indicate that the quantitative differences among motor control patterns. CONCLUSIONS: The results indicate that the motor control pattern could change during incremental pedaling exercise depending on workload.

M - Neuromechanics

P2-M-40 Upper limb and eye movement coordination during goal-directed aiming in a subclinical neck pain population

Navika Cheema[1], Praveen Sanmuganathan[1], Akash Toor[1], Laura Ruberto[1], Paul Yielder[1], Bernadette Murphy[1]
[1]Ontario Tech University

BACKGROUND: Subclinical neck pain (SCNP) refers to mild-to-moderate recurrent neck pain or discomfort that has not yet received any treatment. Previous research indicates that individuals with SCNP experience impairments in upper limb proprioception and alterations in cerebellar processing, due to ongoing changes in afferent feedback from the neck to the cerebellum. Accurate movement planning and execution requires the cerebellum to monitor movement plans based on an accurate body schema

(feedforward processing), and adjust movement execution with the aid of pre-planned strategies as well as visual and somatosensory feedback. Both feedforward and feedback processing are integral for upper limb aiming. Alterations in cerebellar processing seen in SCNP suggests that aiming trajectories are likely to be impacted as these individuals may rely more on visual feedback due to altered neck sensory input impacting the accuracy of the body schema. Thus, this study aimed to determine whether proprioceptive contributions to aiming are altered and whether those with SCNP rely more on visual feedback while performing a vertical upper limb aiming task. METHODS: Ten right-hand dominant participants performed an upper limb aiming task, while wearing an eye-tracking device, 5 SCNP participants (3 females, 2 males) and 5 healthy controls without neck pain. Participants stood in front of a vertically mounted monitor and were set-up with Eye Link II (SR Research, Canada) which was used to track eye movement. A home target was presented at participant's eye level on the vertically mounted monitor. The target then moved either upwards or downwards and participants were instructed to accurately aim with two differently weighted styli (light or heavy) to the new target location. Four blocks of thirty trials were performed for a total of 120 trials. Light and heavy stylus and both upwards and downwards direction were randomized in each block. PRELIMINARY RESULTS: On average, the SCNP group had greater time to peak velocity and greater time after peak velocity compared to controls. Both upper limb and eye response time were much slower within the SCNP group compared to controls. The SCNP group on average, had much longer movement times for both their upper limb and eye, compared to controls. However, there was a limited difference between the SCNP groups primary sub-movement verses the control group. DISCUSSION: These preliminary results suggest that individuals with SCNP have slower response times, longer movement times, and longer times before and after peak velocity. Greater time after peak velocity suggests that individuals with neck pain utilize more feedback processing, specifically visual feedback to guide the limb onto the target. This is evident as the SCNP group had longer eye movement times compared to controls. Slower response time suggests alterations in cerebellar processing and impairments in sensorimotor function. Further data collection is planned.

P2-M-41 Frequency characteristics and orientation of the vestibular-evoked postural response in adolescents with and without idiopathic scoliosis

Jean-Philippe Cyr[1]
[1]*Université Laval*

BACKGROUND AND AIM: Adolescent idiopathic scoliosis (AIS) is a 3D deformation of the spine occurring during growth. It affects 2-3% of adolescents, and the prevalence is ~10 x higher in girls than boys. There is growing evidence that alteration in the processing of vestibular signals results in asymmetrical activity in the vestibulospinal pathway (Woo et al., 2019; Pialasse et al., 2015). Since vestibular cues modulate the back muscles' activity, an asymmetry could relate to the onset or the severity of AIS. An animal study confirmed that asymmetrical vestibular activity caused spine deformation (Lambert et al., 2013). Applying electrical vestibular stimulation (EVS) and characterizing the evoked postural response is commonly used to assess the functioning and symmetry of the vestibular pathway. Objectives: The objectives of the current study were to characterize the vestibular-evoked postural response during bilateral and unilateral EVS in people with and without AIS. METHODS: 30 adolescent girls (15 with and 15 without AIS) participated in this study. Participants received a stochastic EVS (frequency spectrum: 0-25 Hz, amplitude +/- 3mA, DS5 stimulator, Digitimer Ltd) while standing upright on a force platform (model OPTIMA, Advanced Mechanical Technology, Inc.), arms alongside, eyes closed, and head immobilized ~18° tilted upward. Bilateral or unilateral (left or right) EVS induced changes in ground

reaction forces. To characterize the postural response evoked by EVS, we calculated the coherence, cumulant density, gain, lag, and direction of the net vestibular-evoked postural response. RESULTS: Adolescents with AIS showed a larger vestibular-evoked postural response (i.e., peak to peak of the cumulant density) than adolescents without AIS. Adolescents with and without AIS did not present any difference in the symmetry, coherence, gain, lag, or direction of the vestibular-evoked postural response. However, we noticed a tendency in participants with AIS to show a delayed response (i.e., considerable lag) than participants without AIS. CONCLUSION: The larger amplitude of the vestibular-evoke postural response suggests impaired vestibulomotor transformation in AIS.

P2-M-42 Lumbar muscle adaptations to external perturbations are modulated by its mechanical advantage

Julien Ducas[1], Émile Marineau-Bélanger[1], Alessio Gallina[2], Jacques Abboud[1]
[1]Université du Québec à Trois-Rivières, [2]University of Birmingham

BACKGROUND AND AIM: The lumbar erector spinae muscles play an important role in spinal stability. Recently it has been shown that they can be activated by region rather than acting as a single functional unit to better adapt to external perturbations. It has been proposed that muscles can be activated differently depending on their mechanical advantage during complex tasks where joint angle and fibre orientation vary, such as superficial lumbar muscles in trunk movements. In an erect posture, the muscle fibres of the lumbar erector spinae have a posterior and caudal orientation, which generates posterior shear forces to support any anterior reaction shear forces. When the trunk is flexed, however, they are mechanically less efficient to oppose shear forces. Therefore, changing the trunk posture would require adaptations of the erector spinae recruitment. The aim of this study is to investigate if the recruitment of different regions of the erector spinae muscles is modulated by the mechanical advantage of its muscle fibres and trunk orientation. METHODS: Seven healthy adults have already participated in the study and 13 more will be recruited. Participants were exposed to unexpected trunk perturbations to create anterior shear forces. A total of 45 trunk perturbations were induced in 3 different trunk positions: 15 in a neutral erect posture, 15 in trunk flexion and 15 in left trunk rotation. The order of position was randomized between participants and a 10-minute break was added between each position. During these trunk perturbations, muscle activation strategies of the left (LES) and right (RES) lumbar erector spinae were recorded using high-density surface electromyography (two grids of 8x8 electrodes). The root mean square (amplitude of muscle activation) and the medio-lateral and cranio-caudal coordinates of the centroid (spatial distribution of muscle activity) were measured in a 100 ms window centered around the reflex peak. Repeated measures ANOVAs were conducted to assess adaptation of muscle activation amplitude and location of the centroid over time (average of trials 1-5, 6-10 and 11-15) and between positions. RESULTS: A decrease of lumbar muscle activity amplitude was observed across perturbation trials in all three postures in LES ($p=0.02$), but not in RES during trunk rotation. Muscle activity amplitude was different between trunk positions on both sides (LES, $p=0.03$; RES, $p=0.02$), with higher amplitude values in trunk flexion position compared to neutral position on LES ($p=0.01$) and compared to trunk rotation on RES ($p=006$). The centroid location was similar across trials but differed between positions (medio-lateral: LES, $p=0.06$; RES $p=0.02$; cranio-caudal: LES, $p=0.8$, RES $p=0.049$; Figure). CONCLUSIONS: Preliminary results suggest that the lumbar erector spinae muscles strategies of regional activation are modulated by the mechanical advantage of its muscle fibres and trunk position when the stability of the spine is challenged.

P2-M-43 Stretch reflex excitability and the role of texture as non-electrical cutaneous afferent facilitation

Kelly Robb[1], Lara Green[1], Jordan Hyde[1], Stephen Perry[1]
[1]*Wilfrid Laurier University*

BACKGROUND AND AIM: Evidence from electrically evoked cutaneous reflexes supports the role of foot sole cutaneous afferents in modulating the excitability of spinal motorneurons innervating muscles of the lower extremity [1]. This cutaneous reflex facilitation has been limited to electrical stimuli [2]; however, the effect of alternative cutaneous afferent facilitation methods, such as adding textured materials under the foot sole [3], on mechanically induced stretch reflex excitability remains unclear. The purpose of this study was to determine if the addition of texture, as a method of enhancing plantar-surface cutaneous mechanoreceptor feedback, will modify stretch reflex characteristics. METHODS: Thirty healthy young adults (23.2 ± 9 years) participated in 48 block-randomized walking trials of planned gait termination. Cutaneous afferent feedback was either 'non-facilitated' or 'facilitated' (texture added to the walking surface). The walking surface during the second last step of gait termination was unexpectedly manipulated to tilt in two directions: anterior or posterior. In the anteriorly tilted platform perturbations, the ankle moved into plantarflexion generating a stretch reflex (SR) response in the tibialis anterior (TA) muscle. In the posterior tilted platform directions, the ankle moved into dorsiflexion generating a stretch reflex response in the medial gastrocnemius (MG) muscle. All participants were instrumented with a standardized 12-IRED marker setup and kinematics were recorded with two Optotrak Certus cameras (SF=100Hz). Kinetic and EMG data were measured with three AMTI force plates (embedded flush to the walking platform) and a Noraxon Ultium EMG system (SF=1000Hz). The stretch reflex characteristics were comprised of 3 dependent variables: SR latency, as well as peak amplitude (SR Peak) and total amplitude of the agonist burst (SR burst). RESULTS: Results revealed a significant interaction between the direction of platform tilt and cutaneous afferent facilitation on the SR peak ($F_{1,25}=4.25$, $p=0.042$) and SR burst magnitude ($F_{1,25}=8.52$, $p=.004$). There was a significant positive response between SR burst and SR peak texture response in both the anterior platform tilt direction ($r=0.495$, $p=0.01$) and the posterior platform tilt direction ($r=0.714$, $p<0.01$) (Figure 1). CONCLUSIONS: Although our study successfully evoked changes in TA and MG SR characteristics, the role of cutaneous afferent facilitation, via the addition of texture to the walking surface, on modulating spinal motorneuron excitability remains less clear. The significant positive relationships between SR peak and SR burst highlighted the importance of considering inter-subject variability when interpreting results. REFERENCES: [1] Fallon, JB et al. (2005). J. Neurophysiol, 94: 3795-3804. [2] Sayenko DG et al. (2007). Neurosci. Lett, 415: 294-298. [3] Viseux, FJ. (2020). Neurophysiol. Clin, 50: 55-60.

N – Neuromuscular Imaging

P2-N-44 Lumbar multifidus characteristics in university level athletes: Possible predictors of low back pain and lower limb injury

Meagan Anstruther[1], Stephanie Valentin[2], Geoffrey Dover[1], Maryse Fortin[3]
[1]*Concordia University,* [2]*University of the West of Scotland,* [3]*Concordia*

BACKGROUND AND AIMS: Low back pain (LBP) is more prevalent in athletes compared to the general population. Previous studies in athletes with LBP reported a decrease in lumbar multifidus (LM) cross-sectional area (CSA) and increase in side-to-side CSA asymmetry. Similar changes in LM morphology were also associated lower limb injury (LLI) in athletes. However, previous studies mostly investigated

small samples in a single sport at a time. The primary aim of this study was to examine LM morphology and function across a general sample of male and female university level varsity athletes. A secondary aim was to investigate if LM morphology and function are predictors of LBP and LLI. METHODS: 134 university varsity athletes (50 female, 84 male) from hockey, rugby, soccer, and football were included. A self-reported questionnaire was used to acquire player demographics information and history of LBP and LLI in the previous 3 months and 12 months, respectively. Ultrasound images of LM at L5 were obtained bilaterally and measurements of interest included: CSA [Figure 1a),b)], echo-intensity (EI), thickness at rest and contracted [Figure 1c) d)], and % thickness change in both prone and standing positions. DEXA was used to assess body composition. Paired t-tests were used to examine differences in LM measurements between right and left sides and independent t-tests to compare LM measurements between sex. Univariate and multivariate logistic regression analyses were performed to assess if LM characteristics were predictors of LBP and LLI, with sex and players' body composition measurements as possible covariates. RESULTS: Males had significantly larger LM CSA and thickness at rest and contracted in both prone and standing positions (all $p<0.001$). Females had significantly higher EI than males ($p<0.001$). The left LM CSA was significantly larger in males and females in prone and standing (all $p<0.05$). LM thickness at rest and contracted was significantly larger on the left side in males ($p<0.001$) and females ($p<0.05$) in prone. There was no significant difference in % change in thickness between or within males and females in prone or standing. Increased weight (OR= 1.03 [1.01, 1.06], p=0.007) and years played at the university level (OR=1.32 [1.02, 1.71], p=0.03) were associated with a 3% and 32% increased odds of having LBP in the previous 3 months, respectively. Increased LM CSA asymmetry (OR=1.14 [1.01, 1.28], p=0.03) in prone and type of sport (OR=1.44 [1.04, 1.96], p=0.02) were associated with 14% and 44% increased odds of having a LLI in the previous 12 months, with football having the strongest association. CONCLUSIONS: The results provide novel insights into LM morphology and function in a large sample of university-level athletes. Significant differences in LM morphology in prone and standing were observed between male and female athletes. While LM characteristics were not predictors of LBP history in the previous 3-months, increased LM CSA asymmetry was a significant predictor of LLI.

P2-N-45 Behavior of biceps brachii shear modulus in well-trained men after exercise-induced muscle damage

Maria Clara Brandão[1], Lino Matias[1], Liliam Oliveira[1]
[1]*FEDERAL UNIVERSITY OF RIO DE JANEIRO*

BACKGROUND AND AIM: It is well known that exercise-induced muscle damage (EIMD) generates histological changes in muscle tissue that can last up to seven days, approximately. Reduced capacity to generate maximum strength, muscle discomfort, muscle edema and decreased range of motion are indirect and non-invasive variables that describe the EIMD [1,2]. Currently, it is possible to perform the direct evaluation of tissue stiffness in vivo, in a non-invasively, with the Supersonic ShearWave Imaging (SSI) dynamic elastography technique, that quantifies the tissue shear modulus (μ) [3]. Only one study was found about the stiffness of the biceps brachii muscle (BB) after EIMD, and there were no significant changes in the of this muscle in healthy individuals after 48 hours of eccentric exercise (EE) [4]. The aim of the study was to analyze the behavior of μ in two sites of the BB muscle (proximal and distal) of the non-dominant limb of trained men over time. METHODS: The study was approved by the Ethics in Research Committee at Clementino Fraga Filho Hospital, nº 3.031.279, and the sample consisted of 14 men with, at least, 2 years of experience in strength training. The isokinetic dynamometer was used for

sessions of 4 sets of 10 eccentric elbow flexion repetitions with a constant angular velocity of 30º/s and to acquire the isometric peak torque (PT) of the elbow flexors. Elastography images and PT were acquired in 3 visits with a minimum interval of 48h (pre-immediately 10 minutes, 48h and 96h after intervention). RESULTS: Figures 1 shows that the shear modulus and peak torque show a similar behavior. Immediately and 10 minutes after the intervention, there was a significant reduction in PT (p=0.00013 and p=0.00015, respectively), figure 1a. No significant changes in μ were observed for the different portions of BB, as can be seen in figure 1b. CONCLUSIONS: The results indicate that the changes of the shear modulus reflected the behavior of the functional parameter (PT) although lacking for significance. After 48h and 96h, torque recovery was followed by stiffness returning to baseline values. The non-significant decrease in stiffness immediately and 10 minutes later may show that the technique is not able to detect the initial acute changes related to the partial disruption of fibers and passive components of the muscle for well-trained men [2]. The reduction in PT, is expected as previous studies suggest that it is caused by neural, metabolic and structural factors [2,5]. The physiological meaning of the μ-value is yet not fully understood. Our study showed a correspondent behavior of the mechanical property μ and peak torque.

O - Pain

P2-O-46 Painful electrical stimulation of the low back: what is the best configuration to limit stimulation artefacts on the electromyographic signals?

Hélio Cabral[1], Giacomo Nardese[1], Jacques Abboud[2], Paul Hodges[3], Deborah Falla[1], Alessio Gallina[1]
[1]University of Birmingham, [2]Université du Québec À Trois-Rivières, [3]The University of Queensland

BACKGROUND AND AIM: Previous studies have attempted to replicate the temporal aspects of pain by delivering square wave electrical stimuli during specific phases of movement [1]. One of the main limitations of this model is the presence of stimulation artefact on the electromyograms (EMG). A recent study overcame this limitation by inducing experimental knee pain using low-frequency sinusoidal waveforms [2]. Experimental pain studies are commonly performed in the low back but because of the anatomical differences between knee and low back, this novel model may not be directly applied to the low back. Thus, we investigated if this model can be used to experimentally induce low back pain with minimal stimulation artefacts. METHODS: Fourteen healthy volunteers participated. Experimental low back pain was induced by electrical stimuli delivered over the sacrum using different waveforms: sinusoidal at 4 Hz (interelectrode distance, IED, 1 and 3 cm); sinusoidal at 10 and 100 Hz (IED 1 cm); square at 4 and 100 Hz (IED 1 cm). For each configuration, the stimulation intensity was set to induce a pain intensity of 3/10. EMG were recorded during 5s rest period without and 5s with stimulation using high-density electrode grids (14 rows x 4 columns) placed with the most caudal row of electrodes aligned with L5. The differential EMG were band-pass filtered 20-400 Hz and notch-filtered at 50 Hz and harmonics. The stimulation intensity to induce pain intensity of 3/10 was compared between configurations using Wilcoxon signed-rank tests. We compared the root mean square (RMS) of each channel between stimulation and no stimulation using Wilcoxon signed-rank tests; channels with significant (p<0.05) median increase of at least 1μV were considered as affected by stimulation artefacts. RESULTS: The stimulation intensity to induce a pain intensity of 3/10 was significantly higher for square compared to sinusoidal waveforms for both 4 and 100 Hz (p<0.002). Stimulation intensity was similar for sinusoidal at 4 Hz and 1 cm or 3 cm IED (p=0.172). Figure 1 shows the difference of RMS distribution between stimulation and no stimulation conditions for each configuration. For sinusoidal waveforms at 4 Hz and 100 Hz, stimulation artefacts were largely removed when the EMG were detected at least 8 cm from the stimulation electrodes. For sinusoidal at 10 Hz, this distance was 12 cm. Conversely, stimulation artefacts were observed in all channels for 4 Hz and almost all channels for 100 Hz when using square waves. CONCLUSIONS: Lumbar muscle activation can be assessed during electrical painful stimulation with minimal artefacts when the stimulation is provided as a sinusoidal waveform. With the current filtering, 4 and 100 Hz sinusoidal electrical stimuli resulted in the best configuration to collect EMG with minimal artefact as close as possible to the stimulation electrodes. REFERENCES: [1] Tucker et al. 2012; Pain 153(3): 636-643. [2] Gallina et al. 2021; J Physiol 599: 2401-2417.

P2-O-47 Functioning of motor neural circuits in chronic low back pain

Amira cherif[1], Antoine Rohel[1], Mikaël Desmons[1], Guillaume Leonard[1], Amelie Desgagnes[1], Rubens Da Silva[1], Martin Simoneau[1], Catherine Mercier[1], Hugo Masse-Alarie[1]
[1]CIRRIS

BACKGROUND AND AIM: Spine motor control is often modified in non-specific low back pain but the neural origin underlying these changes remains largely unexplored. Corticospinal excitability of back muscle representation tested by transcranial magnetic stimulation (TMS) has been shown to predict the development of chronic low back pain (CLBP). Besides, it has also been demonstrated that the excitability of primary motor cortex (M1) inhibitor circuits is lower in people with CLBP compared to pain-free controls. Otherwise, the vestibulospinal pathway influences the posture and regulation of muscle tone in back muscles and could also underlie alteration in spine motor control and can be tested using electrical vestibular stimulation (EVS). The aim of this study is to determine if motor neural circuits involved in spine motor control are different in CLBP compared to pain-free controls. METHODS: Ten healthy and 10 CLBP (Pain > 3 months) volunteers were recruited and participated in one experimental session. EMG electrodes were positioned over the lumbar erector spinae muscles (LES at L3-L4 level). M1 function was tested using 3 paradigms of TMS: a recruitment curve at 120%, 140% and 160% of the active motor threshold (AMT) with 6 single stimuli per intensity, "short-interval intracortical inhibition" (SICI - paired TMS at 3ms interstimulus interval [ISI]: conditioning stimulus [CS]: at 80% AMT; test stimulus [TS]: at 120% AMT) and "short-intracortical facilitation" (SICF - CS; 120% AMT; ISI: 1.5 ms; TS: at 90%) with 10 single TMS (at 120% AMT-MEP test) and 10 paired-pulse TMS (SICI and SICF) stimuli used. The excitability of the vestibulospinal pathway was tested using 15 stimuli of EVS at 3, 4 and 5mA. EVS elicits a short- and medium-latency responses (sl-vMEP, ml-vMEP, respectively). A stretch reflex was elicited by a direct muscle tap 2 cm above the postero-superior iliac spine using an electromagnetic hammer (short- [R1] and medium-latency [R2] motor responses). A Mann-Whitney U test compared R1, R2, SICF and SICI between groups. Linear mixed models (Intensity x Group) were computed to determine for EVS (short- and medium-latency response) and the TMS recruitment curve. RESULTS: Six men and four women were recruited in each group (CLBP: 36 ± 8 years old; controls: 32 ± 8 years old - p=0.25). A smaller ml-vMEP was present in CLBP (0.03 ±0.03) compared to pain-free controls (0.06±0.03 - main effect: Group | F=7.06; p=0.02). No other between-group difference was detected. CONCLUSIONS: The smaller amplitude of the ml-vMEP in CLBP compared to pain-free controls suggests that the excitability of the vestibulospinal circuits controlling lower back muscles are less responsive to vestibular stimulation. Future studies with larger sample size are critical to better understand these potential alterations in CLBP and if targeting these circuits mays improve management of this condition.

P2-O-48 The Effect of Chronic, Non-Specific Low Back Pain on Superficial Lumbar Muscle Activity: A Systematic Review

Andy Sanderson[1], Alison Rushton[2], Eduardo Martinez-Valdes[3], Nicola Heneghan[3], Alessio Gallina[3],

Deborah Falla[3]
[1]Manchester Metropolitan University, [2]Western University, [3]University of Birmingham

BACKGROUND: Chronic, non-specific low back pain (CNSLBP) is a major global cause of disability. It is thought that one factor which might potentially contribute to ongoing pain is maladaptive variation in the level of activity in the lumbar musculature. Several studies have investigated this activity using surface electromyography, in varied muscles and during a number of functional activities, however the changes in muscle activity previously reported have been conflicting with no clear conclusion for how muscle activity is altered in people with CNSLBP. AIM: This systematic review aimed to investigate how the magnitude of muscle activity is altered in individuals with CNSLBP. METHODOLOGY: This review followed a published protocol (PROSPERO - CRD42019125156) and is reported in line with the PRISMA and PRISMA-P statements. The Web of Science, PubMed, MEDLINE, EMBASE, ZETOC and CINAHL databases were searched, along with grey literature. Two reviewers independently assessed eligibility of studies, and the risk of bias within eligible studies using a modified Newcastle Ottawa Scale. The cumulative quality of evidence was assessed using GRADE. RESULTS: A total of 3367 non-duplicate records were identified and, following screening, 23 studies were included. A narrative approach to analysis was taken due to the heterogeneity within the methodology of included studies. The cumulative quality of evidence in this review was very low, but a majority of studies identified no differences in muscle activity in people with CNSLBP, compared to pain free controls (Fig 1). This result was largely consistent when results were sub-grouped by muscle (paraspinal/multifidus/erector spinae), and type of contraction (static/isometric/dynamic/isotonic). However there was slightly greater consistency in differences in muscle activity identified between groups in the erector spinae, and during both static and dynamic flexion and extension tasks. CONCLUSIONS: It was suggested that further research with more methodologically rigorous studies were required to address this question and increase the quality of evidence. Specifically, studies which investigated muscle activity using HDEMG, and during static and dynamic flexion and extension tasks may be more likely to identify novel results and guide future research for novel rehabilitation approaches.

P - Rehabilitation

P2-P-49 Mechanical versus manual impulse for the propagation of shear wave along the Achilles tendon: a congruent validity study.

Alessandro Schneebeli[1], Deborah Falla[2], Corrado Cescon[1], Marco Barbero[1]
[1]University of Applied Sciences and Arts of Southern Switzerland, [2]School of Sport, Exercise Rehabilitation Sciences, College of Life Environmental Sciences, Universit

BACKGROUND AND AIM: Shear wave tensiometry is an innovative technology for measuring the speed of propagation of mechanical waves along the tendon. Its capacity to characterize the Achilles tendon mechanical properties has been confirmed both in vitro and in vivo. This technology uses accelerometers to measure wave propagation along the tendon generated by a tapping device that provides a mechanical impulse on the tendon. The impulse can be generated also manually using a common reflex hammer, which has potentially positive implications in terms of costs and clinical applicability. The aim of this study was to test the congruent validity of two different methods to generate mechanical impulses (i.e. tapping device versus reflex hammer) given to calculate mechanical shear wave along the Achilles tendon. METHODS: 10 (5 male and 5 female) healthy participants were prospectively recruited. Shear wave propagation along the tendon was calculated using four accelerometers (Analog Devices, ADXL202JE) aligned along the direction of the tendon and equally

spaced at 1.5 cm distance. Impulse on the Achilles tendon to generate shear wave was provided in two different ways, one mechanical impulse provided by an actuator based on electromagnetic transductor and one manual impulse performed by a trained operator with a reflex hammer. Participants were asked to lie on an examination bed with the foot in 0° of plantar flexion and perform two isometric contractions (1 kg-10 kg). A measure was also performed in the relaxed state. The mean of ten impulses was used to calculate the shear wave speed for each condition. Descriptive statistics of shear wave speed for the relaxed state and for the different contraction intensities will be presented as mean ± SD. Congruent validity between the two types of impulse will be calculated using the intraclass correlation coefficient. The Bland Altman analysis will be performed to quantify the agreement between the two methods. RESULTS AND CONCLUSIONS: This study is ongoing and the full results will be presented at the congress. If congruent validity will be confirmed, the manual impulse could increase the clinical applicability of this device in the measurement of tendon properties or to evaluate the effect of exercise on the Achilles tendon mechanical properties.

P2-P-50 Intra-rater reliability of a shear wave tensiometer in the evaluation of Achilles tendon mechanical properties

Alessandro Schneebeli[1], Deborah Falla[2], Corrado Cescon[1], Marco Barbero[1]
[1]University of Applied Sciences and Arts of Southern Switzerland, [2]School of Sport, Exercise Rehabilitation Sciences, College of Life Environmental Sciences, Universit

Background and aim: Different assessment techniques have been developed to evaluate tendon mechanical properties and to characterize tendon response to loading and tendon health status. Recently, a technology using accelerometers, called a shear wave tensiometer, has been presented in order to define the shear wave speed propagation along the tendon and to describe its mechanical properties. The aim of this study was to test the intra-rater reliability of a novel device using the shear wave speed principle for the assessment of the Achilles tendon. Moreover, the capability of this device to detect Achilles tendon shear wave speed changes during isometric contraction was evaluated. Methods: 10 (5 male and 5 female) healthy, asymptomatic participants were prospectively recruited. Wave propagation along the tendon was calculated using four accelerometers (Analog Devices, ADXL202JE) aligned along the direction of the tendon and equally spaced at 1.5 cm distance. Participants were asked to perform isometric contractions at different intensities (0kg-0.5kg-1kg-2kg-5kg-10kg) and the wave speed was calculated for each of the contraction levels. Wave speed on the Achilles tendon was analysed by the same operator on three different days. A test-retest was conducted without repositioning of the participant and the device. A third measure was performed which involved repositioning of the device and participant after one minute rest (intra-rater). Furthermore, two between days measures were performed following 1 and 2 weeks (inter-session). Reliability was calculated using intraclass correlation coefficient (ICC and 95% CI) and standard error of measurement. Shear wave speed between different contraction levels was evaluated using Friedman test. Results: Test-retest reliability was good to excellent (ICC3.1 0.87-0.99) for each of the contraction levels. Intra-rater within session reliability was good to excellent (ICC3.1 0.85-0.96) for each of the contraction levels and inter session reliability was also good to excellent (ICC3.1 0.75-0.93) for each of the contraction levels. The measure at 5 kg showed good reliability but the lower limits of 95% CI were below the cut-off point of >0.6 considered to be the clinically relevant threshold. Friedman test revealed significant differences ($p < 0.01$) in the shear wave speed between all contraction levels. Conclusion: Test-retest, intra-rater and inter-session measures on healthy Achilles tendon with shear wave tensiometer are highly reliable in both a relaxed position and under isometric contractions at different intensities. Changes in Achilles tendon shear wave speed between the different contraction levels has been confirmed, supporting the construct validity of this measurement.

P2-P-51 Quantitative Evaluation of Muscle Function in Parkinson's Disease Patients Undergoing LSVT-BIG® Therapy

Gregorio Dotti[1], Marco Ghislieri[1], Ben O'Callaghan[2], Samanta Rosati[1], Gabriella Balestra[1], Madeleine Lowery[2]
[1]Politecnico di Torino, [2]University College Dublin

BACKGROUND AND AIM: In the last years, several studies have demonstrated the importance of exercise and rehabilitation in the management of patients affected by Parkinson's Disease (PD). Lee Silverman Voice Therapy - BIG (LSVT-BIG®) is an exercise-based treatment reported to significantly improve mobility in PD patients. However, to the best of our knowledge, no studies have examined the effect of LSVT-BIG® on sEMG-based features. Thus, this contribution aims at assessing muscle function of PD patients undergoing LSVT-BIG® through objective indices extracted from sEMG signals. METHODS: A sample population of 12 subjects affected by PD undergoing LSVT-BIG® was retrospectively analyzed using gait data acquired by Flood et al. [1]. SEMG signals were bilaterally recorded from 4 lower-limb muscles during a 10 m overground walk. Data from volunteers were acquired and analysed at three different time-points (Pre, During, and Post LSVT-BIG®). First, sEMG signals were time-segmented into strides based on gait events extracted from acceleration signals recorded at the shank. Second, muscle activation intervals were computed using the previously published LSTM-based muscle activity detector. Third, the Principal Activations (PAs) were extracted from the muscle activation intervals using the optimized version of the CIMAP clustering algorithm [2]. Finally, the Asymmetry Index (AI) [3] and the Global Functional Index (GFI) [4] were computed for each patient of the sample population and each time-point. RESULTS: One-way repeated measures ANOVA revealed no statistically significant changes in terms of either muscle-activation asymmetry and global functional index. More specifically, no changes in AI (Pre: 20.3 ± 1.7, During: 18.8 ± 2.3, Post: 19.7 ± 1.4, $p > 0.28$) and GFI (Pre: 0.83 ± 0.06, During: 0.83 ± 0.06, Post: 0.83 ± 0.05, $p > 0.90$) values were observed in PD patients undergoing LSVT-BIG®. CONCLUSION: This study demonstrated that LSVT-BIG® had no statistically significant effect on either Asymmetry Index or Global Functional Index during overground walking in PD patients. The results suggest no changes in muscle-activation asymmetry and muscle function assessed using the GFI in response to the exercise-based treatment, despite significant increases in gait speed and stride length.
[1] M. W. Flood, B. P. F. O'Callaghan, P. Diamond, J. Liegey, G. Hughes, and M. M. Lowery, "Quantitative clinical assessment of motor function during and following LSVT-BIG® therapy," J. Neuroeng. Rehabil., vol. 17, no. 1, pp. 1-19, 2020. [2] S. Rosati, C. Castagneri, V. Agostini, M. Knaflitz, and G. Balestra, "Muscle contractions in cyclic movements: Optimization of CIMAP algorithm," Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS, pp. 58-61, 2017. [3] C. Castagneri, V. Agostini, S. Rosati, G. Balestra, and M. Knaflitz, "Asymmetry Index in Muscle Activations," IEEE Trans. Neural Syst. Rehabil. Eng., vol. 27, no. 4, pp. 772-779, 2019. [4] S. Rosati et al., "Evaluation of Muscle Function by Means of a Muscle-Specific and a Global Index," 2021.

P2-P-52 Post-operative body composition changes after orthopedic knee surgery

Ashley Herda[1], Christopher Cleary[1], Bryan Vopat[2]
[1]University of Kansas, [2]University of Kansas Medical Center

The purpose of this study was to quantify the degree of change in muscular size following orthopedic knee surgery in otherwise healthy athletes. In a retrospective chart review, 18 patients (12M; 6F: mean±SD: age:18.0±4.9 yrs; ht:175.9.5±19.6 cm) had reported to an orthopedic surgeon presenting a knee injury including the anterior cruciate ligament, meniscus, or combination, requiring repair. Patients were measured for body mass (kg), and body composition [fat mass, lean mass, skeletal muscle, and operative (OP) and non-operative (NO) limb lean mass] using 8-electrode standing bioelectrical impedance analysis prior to, 2- (2W), 6- (6W), 12-weeks (12W), and upon return to unrestricted activity assessment (RTA). Leg circumference at 10 cm superior to the superior patellar pole was also measured on both limbs to indicate swelling or atrophy. Patients followed through their typical rehabilitation protocol as required by their surgeon for up to 9-months post-operatively, or until they passed the return-to-sport assessment. Separate one-way ANOVAs and two 2-way ANOVAs were conducted with an alpha of 0.05 to indicate significance. The one-way ANOVA models indicated a significant change over time for body mass (p=0.03) where pre<RTA (mean difference:MD=1.89 kg; p=0.01), 2W<12W (MD=1.56 kg; p=0.03) and RTA (MD=2.72 kg; p=0.001), 6W<12W (MD=1.15 kg; p=0.03), and RTA (MD=2.31 kg; p=0.01). Fat mass (p=0.001) increased at all time points from pre-operative: 2W (MD=1.33 kg; p=0.01), 6W (MD =1.65 kg; p<0.001), 12W (MD=2.78; p<0.001), and RTA (MD=1.70 kg; p=0.01) and was higher at 12W versus 2W (MD=1.45; p<0.04) and 6W (MD=1.13; p<0.02). Total body lean mass was significantly different from pre and RTS at 2W (p=0.013 and 0.002, respectively), 6W (p=0.008 and 0.025, respectively), and 12W (p=0.013 and 0.006, respectively), with no differences between pre and RTS (p=0.573). Skeletal muscle mass (p<0.001) followed a similar pattern and was significantly different from pre and RTA at 2W (p=0.01 and <0.001, respectively), 6W (p<0.001 for both), and 12W (p<0.001 for both), with no differences between pre and RTA (p=0.68). The 2-way ANOVA (limb x time) for leg lean mass indicated no significant interaction (p=0.072) but there was a main effect for time (p=0.04). Post-hoc analyses indicated a significant difference between pre and 6W (MD=0.19 kg; p=0.02). The 2-way ANOVA for circumference indicated only a main effect for time (p=0.004) with a difference of circumference between pre and 6W (MD=1.53 cm; p=0.01). Overall, there were significant (1.9-3.3%) decrements in body mass after surgery with ~4% difference in skeletal muscle mass and excess 6.2-13.3% increases in fat mass post-operatively, likely due to reduced activity throughout the rehabilitative period. At this point, with a limited sample, there appears to be no inter-limb differences in lean mass nor circumference. However, total-body changes can be identified with a BIA.

P2-P-53 The differences of muscle activation patterns during cervical flexion movement pattern test between torticollis and control

Hirofumi Sageshima[1], Tereza Pospíchalová[1], Patrik Vymyslický[1], David Pánek[1], Dagmar Pavlů[1]
[1]*Faculty of Physical Education and Sport, Charles University*

BACKGROUND AND AIM: The evaluation of movement patterns is one of the common ways to assess functional pathology. The detection of the factors which deviate movement patterns is important in the treatment for chronic musculoskeletal problems. As for idiopathic torticollis patients, co-contraction is one of the most common pathologic features, and up to three-fourth of them have experienced neck pain. Although both symptoms of cervical dystonia could be a cause of different cervical flexion movement patterns, there is a limited number of studies that investigated it for this type of patients. This study aimed to determine how the cervical flexion movement pattern of torticollis patients deviate from the young healthy control group with the comparison of muscle activation patterns. METHODS: Eight torticollis patients (aged 27-68) and eight young healthy controls (aged 20-29) made a consensus and voluntarily participated in this experiment. For a torticollis group, we measured the Toronto Western Spasmodic Torticollis Rating Scale (TWSTRS), which scored 39.9 (9.7) averagely at first. All participants performed the conventional cervical flexion on supine position according to Janda's movement pattern test for 15 times repeatedly to produce repetitive patterns and the measurement of muscle activation from 5 paired muscles (suprahyoid, infrahyoid, sternocleidomastoid, scalene and trapezius descending fibre) was implemented with surface electromyography (EMG). Each motion was in a cycle, and 8 consecutive cycles in the middle were averaged. Then, the duration to reach the peak value were compared by unpaired samples t-test between 2 groups, and the difference of average muscle activation patterns between 2 groups was calculated by cross-correlation in each measured muscle. RESULTS: Sternocleidomastoid muscles in a torticollis group showed a significantly longer duration to reach the peak value during conventional flexion compared with a control ($p<0.05$), but other muscles did not show statistical differences. In the analysis of average muscle activation patterns, its patterns from torticollis showed weak to moderate correlation with ones from control in all measured muscles, especially sternocleidomastoid, scalenes and trapezius muscles had weaker correlation coefficients ($r=0.31$-0.54) than hyoid muscles ($r>0.6$). CONCLUSIONS: The persistent activation was found in both agonists and antagonists of cervical flexion in torticollis patients, and it could be a cause of recording different muscle activation patterns from a control group. Especially in trapezius muscle, the bilaterally significantly increased activity found in patients with torticollis was independent of the side of the disability and may therefore represent one of the compensatory mechanisms of neck muscle coordination in these patients.

R – Sports Science and Motor Performance

P2-R-54 Muscle activation of the medial and lateral head of the gastrocnemius muscle during isometric plantar flexion in university level runners and non-runners

Timothy Green[1], Jacqueline Toner[2], Usha Kuruganti[1]
[1]University of New Brunswick, [2]Dalhousie University

BACKGROUND AND AIM: Running is a common activity that utilizes the gastrocnemius muscle for plantar flexion throughout the movement. Numerous studies have examined running physiology, however few studies have examined the role of the gastrocnemius muscle. Additionally, few studies have compared muscle activity patterns between runners (R) and non-runners (NRs) to examine neuromuscular differences. Such information could provide insight regarding muscle activation in trained athletes and inform practitioners how to improve training protocols. Examination of this muscle may also provide valuable information regarding muscle behaviour. The aim of this exploratory study was to compare the strength and muscle activation of the medial and lateral gastrocnemius muscle during low, moderate, high and maximal ramped isometric plantar flexion contractions in runners and non-runners. METHODS: Fifteen male (n=6) and female (n=9) individuals (mean 21.7 ⍰ 1.4 years) participated in this study. The R group consisted of seven runners who were members of a university track and field team and trained competitively 4-6 times per week. The NR group was composed of eight general population university students that completed intentional aerobic activity no more than twice per week. Participants were asked to complete three trials of 25%, 50%, 75% and 100% output of their pre-recorded maximal torque using an isokinetic dynamometer (Cybex, Humac Norm) with feedback. Torque data was compared between groups for each condition. Surface electromyography (sEMG) data was collected using bipolar electrodes placed over the lateral and medial gastrocnemius of each leg (Delsys, Natick, MA, USA). The most consistent trial was used for comparison of torque, sEMG root

mean square (RMS) and median frequency (MF). Significant differences between the independent and dependent variables were determined using a mixed model ANOVA (RStudio 1.0.136, Boston, MA). Pairwise t-tests with Bonferroni post-hoc correction were used to identify significant results ($p<0.05$). RESULTS: Preliminary results suggest potential training effect due to significant differences in mean torque as shown in Figure 1.0. Within the NR group, males produced significantly greater mean torque values than females ($p<0.001$). However, no significant differences in torque output were noted between males and females in the R group ($p=0.19$). Finally, no significant differences were detected in RMS or MF between the R and NR groups. CONCLUSIONS: Few studies have compared the muscle activation of the gastrocnemius during isometric plantar flexion between trained and untrained individuals. In this exploratory study, no significant differences were detected between runners and non-runners in terms of strength, RMS or MDF, however, preliminary results suggest that biological sex may impact non-runners to a greater extent than runners. The lack of significance between the R and NR groups may be due to the low sample size, however these are preliminary results and data collection is ongoing.

P2-R-55 Does an increase in maximal upper body strength lead to enhanced sprint kayak performance?

Mathias Kristiansen[1], Ann-Marie Pedersen[1], Ghita Sandvej[1], Patrick Jørgensen[1], Jarl Jakobsen[2], Kent Klitgaard[1]
[1]Aalborg University, [2]Team Danmark

BACKGROUND AND AIM: Optimal performance in the 200m flat-water sprint kayak discipline is heavily dependent on the ability to generate anaerobic power. As anaerobic power in kayaking can be expressed as maximal power output per stroke, it is inherently limited by muscle strength, more specifically upper body strength. Therefore, the aim of the present study was to investigate whether an increase in maximal upper body strength would elicit a concomitant change in 200m kayak sprinting performance. METHODS: Twenty-six national elite junior A, U23, and senior kayak paddlers (16 men: age 18.6±4.1 years and 10 women: age 17.0±1.4 years) from three regional kayak centers participated in the study. Participants were stratified based on gender, kayak center and 1 repetition maximum (1RM) in bench press and thereafter randomly allocated into two groups, a training group (TRAIN), and a maintenance group (MAIN). Each group completed a six week strength training intervention. The purpose of TRAIN was to increase 1RM in bench press and maintain strength levels in all other exercises, while the purpose of MAIN was to maintain the strength in all exercises performed. Pre- and post-tests were carried out in 200m ergometer kayak sprint, 1RM bench press and 1RM bench pull. RESULTS: TRAIN significantly increased 1RM strength in bench press (pre: 87.3±21.2 kg, post: 93.9±21.3 kg, $p = 0.001$) and bench pull (pre: 85.0±15.0 kg, post: 87.0±15.0 kg, $p = 0.025$). No significant differences were observed in MAIN from pre-test to post-test in 1RM strength for bench press (pre: 93.3±26.5 kg, post: 94.6±28.7 kg, $p = 0.408$) or bench pull (pre: 85.4±21.2 kg, post: 86.6±20.2 kg, $p = 0.461$). In the 200m kayak ergometer sprint test, TRAIN significantly decreased the time to complete the test (pre: 44.7±4.1 s, post: 44.2±4.2 s, $p = 0.042$), while no significant difference in performance was observed in MAIN (pre: 45.7±4.4 s, post: 45.6±5.3 s, $p = 0.89$). CONCLUSIONS: This is the first study to show a causal relationship between a strength training-induced increase in upper body strength and a concomitant decrease in 200 m sprint kayak time. The increase in upper body strength most likely leads to an enhanced ability to generate anaerobic power, thus increasing sport-specific performance.

P2-R-57 Muscle synergy of grading ability in table tennis

Yuki Sato[1], Yukihiko Ushiyama[1], Shuhei Kameyama[2], Kengo Wakui[1], Kazuto Kamitaira[1]
[1]Niigata University, [2]Niigata university of management / Niigata University

BACKGROUND AND AIM: In sports, controlling force exertion is generally called grading ability. In the study of grading ability in hitting, the subjective effort at total effort is set as 100%, and the ability to control force exertion according to changes in the effort is clarified. Table tennis players sometimes swing as hard as they can to hit a fastball. On the other hand, the ability to control the exertion of force is essential because the player may hit the ball with less effort for accuracy. However, it is unclear how muscle synergy is affected by the ability to exert force during the table tennis stroke. This study aimed to investigate the relationship between personal effort and muscle synergy in table tennis forehand strokes using muscle synergy analysis. METHODS: Subjects hit the ball ten times consecutively per stage of the forehand stroke in five levels of personal effort (60%, 70%, 80%, 90%, and 100%). The sEMG of eleven upper limb surface muscles involved in the forehand stroke were recorded. The motion was captured by five motion capture cameras and used to extract the analysis intervals. The obtained sEMG data were filtered, and ARVs were calculated. The data from the ten trials were then averaged, and a non-negative matrix factorization was performed to estimate the muscle synergy vector and synergy activity coefficient. RESULTS: Two muscle synergies were extracted in the forehand stroke with five phases of force exertion. These synergies were activated in the forward swing and follow-swing phases before and after impact. The muscle synergy profile and weighting coefficients were similar, as the synergy activated did not change when force exertion was adjusted stepwise. CONCLUSIONS: The table tennis forehand stroke consisted of synergies in the forward swing phase before and after impact and the follow-swing stage. The results also showed no differences in muscle synergies due to the step-by-step exertion of force. In conclusion, the table tennis forehand stroke showed consistency of muscle synergies by the ability to exert force.

S – Wearable Sensors & IoT

P2-S-58 Artificial Intelligence Based Muscle Activity and Muscle Monitoring Tracker with Wireless Sensor System

R Majidi[1], A Kiapour[2], V Entezari[3], M Ghasemi[4], Z Zhang[5], E Clancy[5]
[1]OrthoKinetic Track LLC, [2]Massachusetts General Hospital, Harvard Medical School, [3]Cleveland Clinical Foundation, [4]University of Massachusetts Chan Medical School, [5]Worcester Polytechnic Institute

BACKGROUND: The shoulder, the most mobile joint in the body, is prone to injury, dislocation, and degenerative diseases. A growing number of patients undergo surgical procedures and require prolonged rehabilitation to regain their range of motion (ROM) and function (Khoschnau, et al., 2020). We propose an artificial intelligence (AI)-based wearable device which is temporarily attached to the joints for tracking kinematics and electromyogram (EMG) activity of patients after shoulder surgery. The device can lower medical costs through remote sharing of real-time joint ROM and muscle activity data, reduce the need for in-person hospital/physical-therapy visits and increase patient engagement through goal-oriented recovery feedback. The outcome of surgical interventions is commonly measured by improvement in shoulder pain, ROM, strength, and patient-reported outcome measures. These outcomes still rely on physical examination, which is highly variable and inaccurate. Also, timely assessment of ROM and appropriate interventions by physical therapists are critical to avoid stiffness and development of postoperative complications. MATERIALS/ METHODS: We used a prototype sensor-based wearable joint ROM and muscle activity monitor to assess two subject's shoulder joint function.

The subjects were an 82-year-old right-handed healthy man with no history of shoulder girdle muscle or joint disease or surgery, and a 74-year-old right-handed man with right shoulder stiffness due to right rotator cuff injury-related shoulder surgery. The subjects performed motions using their shoulder joints with the wearable device attached to their shoulder. RESULTS: Fig. 1 shows the ROM of subjects during shoulder abduction and external rotation, and elbow flexion (top); and EMG RMS (bottom). Each plot is one combination of handedness (left, right) and task (flexion, abduction, external rotation), as labeled. The injured subject had lower ROM than the healthy subject for all three movements. In flexion movement, a deltoid muscle contribution calculation in the injured subject was 6.53%, while in the healthy subject it was 16.1%. The maximum flexion angle in the affected right shoulder of the injured subject was 110°, compared to 146° in the same shoulder of the healthy subject. CONCLUSIONS: Our powered adjustable brace aims to reduce recovery time by giving real-time feedback to the user during postoperative rehabilitation, improve ROM and optimize pain control. Measurements from the device's four surface EMG sensors and the triaxial accelerometer-gyroscope can be transmitted wirelessly to healthcare cloud/storage for further processing. In the healthcare cloud, an AI-based algorithm will estimate the impairment of individual shoulder girdle muscles. This technology can be used for remote at-home telemedicine delivery of rehabilitation services while tracing tele-visit sessions in compliance with billing standards as in-person visits.

P2-S-59 Markerless Motion Capture Systems in Pediatric Sports Medicine: A Scoping Review

Erica Bitektine[1], Samuel Lamanuzzi[1], Marianne Gagnon[1], Louis-Nicolas Veilleux[1]
[1]McGill University/Motion Analysis Center, Shriners Hospital for Children

BACKGROUND AND AIM: Sports-related injuries are common among youth, with roughly 18% of 12-19 year olds suffering from yearly injuries [1]. Recent literature suggests the importance of movement quality in injury occurrence, prompting the need for better kinematic evaluation methods. Currently, most kinematic data are collected via marker-based motion capture systems (MoCaps), which are limited to the laboratory, dependent on marker placement and time consuming. In contrast, markerless MoCaps, which include inertial and camera-based systems, are cost and time effective, as well as portable outside of the laboratory. The objective of this scoping review is to understand the current state of literature and identify research gaps that need to be addressed to better understand the potential of markerless MoCaps in assessing youth rehabilitation, performance, and injury prevention in sports medicine. METHODS: A search in Medline, Scopus and SPORTDiscus was conducted in July 2021. The inclusion criteria were a) subjects aged 0 to 24 years old, b) research involving rehabilitation, performance or injury prevention, c) including a description of the markerless MoCap post-processing methods, e) published in English or French. The principal exclusion criteria were low acceleration speeds and age. General information (origin, publication date, study type), methods (population characteristics, markerless MoCap(s) used and their placement location, post-processing methods), results and conclusions were synthesized. RESULTS: 734 non-duplicate articles were identified, 68 of which met the eligibility criteria. Among them, 62 studies used inertial measurement units (IMUs) to obtain biomechanical data. Most assessed performance (n = 44), while the rest examined injury prevention and rehabilitation. The non-IMU studies used Microsoft Kinect® (n = 4) and camera-based systems (n = 2). Preliminary results showed the feasibility of using markerless MoCaps to identify outcomes linked to injury risk, such as increased workload, fatigue, ground impact and certain limb kinematic parameters, as well as performance metrics with fair reliability. However, the review revealed IMU limitations, including sensor drift, skin artifacts, and limited assessment range. Among non-IMU systems, Kinect®

failed to provide accurate assessment of fine movements. Many studies had small sample sizes, as well as limited body distribution of sensors and number of movements. CONCLUSIONS: This review suggests that markerless MoCaps 1) have good portability and applicability to a broad range of assessments, 2) could be used to establish injury risk assessment tools, following further research on injury-related parameters. However, more robust studies are needed to assess the validity and reliability of markerless MoCaps, and to identify the best methodology for their use. 1. Billette , J.-M., & Janz, T. (2015). Health at a glance. Injuries in Canada: Insights from the Canadian Community Health Survey.

P2-S-60 Effect of electrode configuration on the quality of surface electromyography signals detected with dry electrodes

Elmar Junker[1], Catherine Disselhorst-Klug[1], Elisa Romero Avila[1]
[1]Institute of Applied Medical Engineering, RWTH Aachen

Although pre-gelled electrodes are mostly used in medical applications, the usability issue of personalized and self-positioned wearable devices, which include information about muscular activation, require the use of dry electrodes for the recording of the surface electromyography (sEMG) signals. Nevertheless, these type of electrodes usually have a worse signal-to-noise ratio and a higher susceptibility to interference compared to the pre-gelled ones. Additionally, there are no recommendations concerning electrode size, inter-electrode distance and electrode-shape for dry electrodes. The aim of this work is to stablish an appropriate dry electrode arrangement by analyzing the effect of inter-electrode distance (IED) and electrode diameter on the sEMG signal energy and quality. For this, two electrode arrays with a 10 mm IED were considered. Each array consisted of six, dome-shaped silver electrodes with a diameter of either 5 mm or 8 mm. The electrode arrays were assessed during an isometric contraction of the biceps brachii and the influence of electrode position and repeatability of measurements were analyzed. The results showed that the relative position of the electrodes on the array is important for the quality of the recorded sEMG signal. The inner-located electrodes provided more stable signals with lower noise as compared to the outer electrodes. This can be explained by the influence of the muscle's physiology and the location of the electrodes at the edge of the array. Furthermore, the IED had a pronounced effect on the sEMG signal. As the spacing between the electrodes increased up to 30 mm, the signal energy and quality significantly increased but the data became more dispersed. Since the optimal IED should be a compromise between high signal energy and quality, and relatively low variability with a small risk of crosstalk, an IED between 10 and 20 mm is recommended when using dry electrodes in a bipolar configuration. Regarding the electrode size, no effect between both sizes was observed during long-term measurements on the sEMG signal energy and quality. However, it was found that a bigger diameter electrode required more time to stabilize and provide consistent measurements than the 5 mm-diameter electrode. These findings confirm a previous work where no benefits were found in the RMS of the sEMG envelope when the diameter of the electrode was above 5 mm. Moreover, a smaller diameter may be preferable in situations where space is a crucial factor. These findings can be used as a reference to identify an appropriate arrangement of dry electrodes in wearable devices that detect muscular activation. This will ensure that the outcomes are based on repeatable, high quality sEMG signals.

P2-S-61 Accelerometry-based metrics to characterize upper extremity motor deficits during a kitchen task among adult living with cerebral palsy

Isabelle Poitras[1], Jade Clouâtre[1], Alexandre Campeau-Lecours[1], Catherine Mercier[1]
[1]Laval university

BACKGROUND AND AIM: Activities of daily living (ADL) require the use of both arms in a coordinated manner. People living with cerebral palsy exhibit both unimanual and bimanual deficits. Accelerometry allows quantifying the relative use of each arm in different tasks, in different neurological populations and over an extended period of time. However, the capacity of accelerometry-based metrics to discriminate among the level of deficits have been questioned. Moreover, the majority of studies addressing this concern targets stroke survivors or children with CP, while little is known about adults living with CP. The aim of this study is to describe unimanual and bimanual functions in adult living with CP during ADL based on accelerometry-based metrics. A second aim is to test whether these accelerometry-based metrics discriminate across levels of deficits. METHODS: Fourteen adults living with CP have been recruited to perform a simple kitchen task while wearing an accelerometer on each wrist (Actigraph GT9X). They were selected to represent three levels of upper extremity function based on the Manual Ability Classification System (MACS I (n=5), II (n=5), III (n=4)). Vector magnitude (VM) was calculated based on the accelerometry data allowing to identify whether movement was present at each arm for each time epoch (VM > 100 = movement). This allowed to calculate two unimanual metrics (% of dominant use and % of non-dominant use) and one bimanual metric (% of bimanual use) representing respectively the amount of use of each arm separately and simultaneously. A Friedman test was performed to determine if each metric was able to discriminate between the different MACS levels. The alpha threshold was set at p-value <0.05. A visual representation of the intensity of movements was also performed to characterize the activity intensity among MACS levels based on a bimanual metric (bilateral magnitude= intensity of use of both arm) and an unimanual metric (magnitude ratio= ratio of activity intensity between each arm). RESULTS: The % of bimanual use, the % of dominant use and % of non-dominant use significantly different across MACS levels (% of bimanual use: I= 21.6%, II = 27.3%, III= 16.2%; % of dominant use: I= 53.9%, II= 64.7%, III=79.1%; % of non-dominant use: I =24.5%; II= 8%; III= 4.7%). The graphic representations of the degree of activity intensity allow to distinguish among the MACS levels, as a lower intensity of activity (bilateral magnitude) is observed for MACS level III than for levels II and I. The magnitude ratio shows that adults living with a MACS III exhibit a larger relative use of their less affected arm. CONCLUSIONS: The tested accelerometry-based metrics allow discriminating among different levels of deficits during a representative ADL. This suggests that these metrics could be used to follow the progress of a patient over time, but more studies are required to assess the sensitivity of these metrics to smaller clinical changes

Poster Session 3

Saturday June 25, 2022

A - Aging

P3-A-1 The effects of mechanical, postural and cognitive manipulations on stability measures of dynamic balance during beam walking in older adults

Andréia Abud da Silva Costa[1], Tibor Hortobágyi[1], Rob den Otter[1], Andrew Sawers[2], Renato Moraes[3]
[1]University Medical Center Groningen, [2]University of Illinois at Chicago, [3]University of São Paulo

BACKGROUND AND AIM: Beam walking can be an appealing paradigm for detecting mild impairments in dynamic balance and identifying older adults at risk for falls. During this task, the base of support is reduced, affecting dynamic balance, particularly when the center of mass (COM) is transferred while one leg is on the beam. This task may induce a loss of balance, causing a step off or a 'fall'. Manipulation of beam width, arm position, and cognitive load during beam walking can produce additive and interactive effects on dynamic balance, increasing task difficulty, changing balance control strategies, and being potentially more effective in detecting subtle balance impairments. Thus, we examined the additive and interactive effects of manipulating beam width, cognitive task (CT), and arm position on stability measures of dynamic balance during beam walking in older adults. METHODS: Older adults (n=24, 69±4y) walked on 6, 8, and 10-cm wide beams (2-cm high, 4-m-long), with and without CT (sequential subtractions by 3), with three arm positions (free, crossed, akimbo). We used the Plug-in Gait Full Body model of the Vicon system to estimate the whole-body COM position and calculate the trunk angular acceleration. We computed the root mean square (RMS) of the COM displacement and the trunk acceleration in the frontal plane to assess stability. RESULTS: The results showed that progressively decreasing beam width increased trunk acceleration RMS (p=0.002; Figure 1A). The RMS of trunk acceleration was 15% and 24% higher on the 6-cm (168.1±63.4 º/s2) than on the 8-cm (146.6±44.0 º/s2; d=0.5) and the 10-cm (135.6±45.8 º/s2; d=0.72) wide beams, respectively. RMS was also 8% higher on the 8-cm than on the 10-cm wide beam (d=0.3). This variable was also affected by the arm position (p=0.009; Figure 1B), being 7% lower in the akimbo position (144.2±50.4 º/s2; d=0.28) when compared with the arms crossed condition (155.2±55.8 º/s2). There was also an interaction between CT and arm position only for trunk acceleration RMS (p=0.044; Figure 1C). It was 9% lower in the CT plus arms akimbo condition (137.6±50.2 º/s2) compared with the CT plus arms free (151.2±51.2 º/s2) and arms crossed conditions (151.5±58.5 º/s2). CONCLUSIONS: The COM displacement RMS was not affected by any manipulation. In general, beam narrowing made the task more difficult and increased trunk movements, suggesting a need for constant trunk adjustments to keep the COM within the base of support. Only akimbo position reduced trunk acceleration RMS probably allowing individuals to have a slightly better balance control by moving the elbows back and forth, minimizing arm actions in relation to the trunk, and reducing its influence on trunk acceleration. In conclusion, participants performed effective trunk adjustments to control COM position and keep dynamic balance during beam walking, even during more difficult conditions. Funding: FAPESP/Brazil (Grant 2018/18081-0).

P3-A-2 The relations between postural stability of elderly females living independently and their physical characteristics

Mayumi Kuno-Mizumura[1], Yui Kawano[2], Junko Kikuchi[1], Chiharu Oka[1], Ayako Ito[3], Kaoruko Iida[1]
[1]Ochanomizu University, [2]Japan Institute of Sports Science, [3]Nagoya City University

BACKGROUND AND AIM As the population of elderly adults increases, the incidence of frailty syndrome, a reduction in physiological reserve across multiple physiological systems. To prevent facility syndrome likewise increases. Impaired balance has been associated with age should be determined to prevent frailty syndrome; however, affective factors to postural stability in independent elderly people have not been fully elucidated. METHODS Sixteen elderly females aged from 62 to 85 years old living independently who had no regular exercise experience participated in this study. They were asked to stand on the force platform (Kistler) for 30 seconds with or without performing attention demanding cognitive tasks (mathematical counting) while standing with eye-opened. Additionally, they stand on the force platform for 30 seconds with eye-closed. The ground reaction force was recorded at 100Hz and calculated the center of pressure (COP) during three standing conditions; Eye-opened (EO), Eye-closed (EC), and dual-task (DT) condition. To evaluate the postural stability, total path length and rectangular area of COP were calculated. Using ultrasound apparatus, adipose tissue and muscle thickness was also measured to evaluate anthropometric characteristics. Sit-and-reach test, two-step test, and functional reach test were performed to evaluate physical fitness characteristics. RESULTS . A significant positive correlation between rectangular are of COP and age was obtained only during EC condition. Significant negative correlations were observed between path length of COP during all three conditions and body weight, BMI, hip circumstance, waist circumstance, thigh circumstance, and calf circumstance. Significant negative correlation between path length of COP and muscle thickness of quadriceps muscle, tibialis anterior muscle, and abdominal muscle were obtained. Flexibility evaluated by the sit-and-reach test has a significant negative correlation with a path length of COP during all three conditions.Some previous studies have reported that frail elderly showed a decline in postural stability compared to non-frail elderly (Marques et al, 2017, Shinohara et al,2021) However, it is not clear about the affective factors which would induce decline of postural stability of elderly adults who can live independently. From the results of this study, muscle volume of lower limb and flexibility would be one of the physical factors related to their static postural stability. Postural stability during dual-task in this study showed a significant positive relationship with that without a cognitive task. CONCLUSION From the results of this study, among elderly adults living independently, it is suggested that maintaining body weight including muscle volume and flexibility would influence their postural stability.

P3-A-3 Impact of prolonged bed rest on H-Reflex response and strength in older adults

Mathil Ruel[1], Jean-Christophe Lagacé[1], Philippe St-Martin[1], Karen Lambert[2], Eléonor Riesco[1], Mathil McPhee[3], Guillaume Léonard[1], Isabelle Dionne[1]
[1]Centre de recherche de l'Université de Sherbrooke, [2]PhyMedEx, [3]Manchester Metropolitan University

Introduction Immobilization affects multiple systems, including the neuromuscular system. Loss of strength is one of the negative effects of immobilization and can affect an individual's balance and autonomy, especially in the elderly. Previous studies have reported altered Hoffman reflex (H-Reflex) responses in soleus muscles of younger individuals undergoing unilateral limb suspension. This suggests a possible remodeling of the motoneurons involved in the innervation of the lower limb with immobilization. Limb suspension, however, allows the participant to keep their mobility, which presents a limit when trying to understand the impact of complete immobilization, such as prolonged hospitalization. To this day, very little is known on the impact of prolonged immobilization in older adults H-Reflex responses and how countermeasures like exercise can mitigate the deleterious effects. Objectives We sought to verify if 2 weeks of head-down bed rest changes the soleus muscle H-Reflex response in healthy adults aged between 55 and 65 years and if an exercise countermeasure minimizes the deleterious effect of bedrest. The second objective of the study is to determine if there is a relationship between changes in lower limb muscle strength and H-Reflex responses after bed rest. Method Twenty-four healthy adults aged between 55 and 65 years were recruited for this study. They underwent 14 days of head-down bed rest at the McGill University Health Centre in Montréal, Canada. Half of the participants acted as a control group and were mobilized daily by a physical therapist. As for the experimental group, they engaged in an hour of daily exercise divided into 3 sessions. The exercise sessions consisted of a combination of continuous aerobic, High Intensity Interval Training (HIIT), and resistance training targeting the entire body. The excitability of alpha-motoneurons was measured in the right leg using surface EMG electrodes to record the gastric-soleus muscle. An electrical stimulus of 1000 microseconds was applied over the tibial nerve, increasing the intensity progressively in 1 mA increments until the H-Reflex peak was reached. The same intensity steps were repeated to reach the maximal M wave (maximal action potential of the muscle), and the H max/M max amplitude ratio was calculated for each subject. Maximal handgrip and knee extension strength were measured using quantitative muscle dynamometry (handheld dynamometer and Biodex, respective Results Data collection is currently ongoing, but preliminary analyses suggest that HDBR did not affect neuromotor activity in elderly bedridden for 2 weeks for neither of the groups (intervention and control). The complete results will be presented at ISEK 2022.

P3-A-4 Aging of skeletal muscles: A shear wave elastography approach to detect changes in mechanical properties in vivo

Manuela Zimmer[1], Benedict Kleiser[2], Justus Marquetand[2], Filiz Ates[1]
[1]University of Stuttgart, [2]University of Tübingen

BACKGROUND AND AIM: Skeletal muscle performance changes with age. Ultrasound shear wave elastography (SWE) was shown to represent in vivo muscle mechanics both in active [1] and passive [2,3] states. Hence, it has the potential to show muscular changes occurring due to aging non-invasively. We aimed to investigate the mechanical properties of the biceps brachii muscle (BB) using SWE in relation to elbow joint position and function. We hypothesized that SWE does reflect the changes in mechanical properties of the BB due to (i) activity level changes, (ii) length changes imposed by the joint position, and (iii) aging both in passive and active states. Therefore, SWE offers an advanced understanding of alterations in individual muscle's contribution to joint function with age. METHODS: Healthy young (7 males, 7 females, 28.07 ± 5.06 years old) and older (5 males, 5 females, 67.80 ± 5.69 years old) adults participated. Simultaneous electromyography and SWE of the BB and isometric elbow torque measurements were performed at five elbow angles (60°, 90°, 120°, 150°, and 180°). The BB was investigated during rest, maximum voluntary contraction (MVC), and isometric ramp contractions (up to 25%, 50%, and 75% of MVC torque). The shear elastic modulus was deduced from SWE. Two- or three-way ANOVA was performed to detect effects of joint position, activity level, and age. RESULTS: At passive state, the shear elastic modulus increased with increasing elbow angle for both groups ($p<0.001$). Significant differences were found between 60° and 120°/150°/180° ($p<0.001$ for all) and 90° and 150°/180° ($p<0.001$, $p<0.01$). Shear elastic modulus was higher for the older adults compared to the young ($p<0.001$). Differences located at 120° and 150° elbow angles were more than twofold. MVC torque was lower for older adults ($p=0.01$) with the highest torque obtained at 60° elbow angle, decreasing with the increasing angle for both age groups ($p<0.001$, Fig 1). During sub-maximal contractions, the active shear elastic modulus changed significantly with joint position, activity level, and age ($p<0.001$ for all). CONCLUSIONS: The present findings support the hypotheses posed. We found that for both active and passive states, the shear elastic modulus represents muscle's length-dependent force production characteristics in vivo. The shear elastic modulus increased with increased torque for each joint position. Moreover, SWE reflects the decreased active force production capacity with age, and in the passive state, it detects the increased stiffness that occurred due to aging. Our findings suggest that SWE can also be used to detect muscular alterations following e.g. neuromuscular diseases. Acknowledgments: Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) GRK 2198-277536708. References: [1] Ates F. et al. 2015, J Electromyog Kinesiol, 25:703-708 [2] Ates F. et al. 2018, Eur J Appl Physiol, 118:585-593 [3] Eby S.F. et al. 2015, Clin Biomech, 30:22-27

B – AI, Data Fusion, and Machine Learning

P3-B-5 Analysis of walking characteristics between genders, based on full-body kinematic gait data

Svonko Galasso[1], Renato Baptista[2], Mario Molinara[1], Rocco Calabrò[3], Alessandro De Nunzio[2]

[1]*University of Cassino and Southern Lazio,* [2]*LUNEX International University of Health, Exercise and Sports,* [3]*Istituto di Ricerca e Cura a Carattere Scientifico Centro Neurolesi "Bonino Pulejo"*

BACKGROUND AND AIM: Objective analysis of motor recovery during gait (Gait Analysis, GAn) in clinic is an essential motor assessment to improve clinical decision making and provide precision rehabilitation approaches to recover gait functions. GAn is a standard diagnostic laboratory procedure to quantitatively assess and analyse the human body motion during the execution of the functional motor task of walking. GAn is usually based on wearable motion sensors or camera-based systems, which generates an extensive set of data describing several features of human motion. Such amounts of data are difficult to be managed, analysed and interpreted. This makes the GAn a time-consuming unfeasible assessment approach in clinical practice. Machine Learning (ML) and Deep Learning (DL) techniques can provide a viable solution, as they can handle massive time series and complex data. ML and DL techniques are widely used in multiple fields such as medical diagnosis, pattern recognition, image processing, therefore, making them suitable for GAn. Such approaches can provide summative information of a condition or level of impairment analysing the extensive features of motion data generated in GAn. This study aims to correctly classify the gender of the subjects, using different ML and DL models and full-body kinematics gait data provided by wearable wireless Inertial Measurement Unit (IMU) sensors. METHODS: Kinematic gait data were collected from 41 healthy subjects (25 male and 16 female, 23 years old ± standard deviation of 3 years) while walking on a treadmill at natural speed. For each subject, 40 continuous gait cycles were selected by identifying the heel strikes using foot acceleration data. As a preliminary step, different ML and DL methods were tested combining the different acquired kinematic features (3D joint range of motion from the trunk and the right lower limb). The classification algorithm has been based on continuous wavelet transform (CWT) and a deep convolutional neural network (CNN). Images from the kinematic features were obtained by creating a time-frequency representation of the input signals (scalograms). RESULTS: Several CNNs have been trained and tested to validate the effectiveness of the approach. From the original dataset, different image datasets were derived from the kinematic features, achieving at least 60% accuracy on unseen data. CONCLUSIONS: The presented work served as a preliminary test on using ML and DL techniques to extract clinically relevant information from kinematic data for future approaches to discriminate across levels of impairment instead of gender.

P3-B-6 Segmentation of sEMG using time-series analysis

Julia Meneley[1], Dawn MacIsaac[1], Erik Scheme[1]
[1]*University of New Brunswick*

BACKGROUND AND AIM: Surface electromyography (sEMG) signals provide a non-invasive indicator of muscle contraction activity. This contributes to its applicability in many fields such as diagnostic testing in clinical settings, myoelectric control of prosthetic devices, and identifying the onset and offset of movements in experimental research. The segmentation of sEMG signals classically relies on thresholds for onset and offset detection. When performing cyclic or repetitive tasks, matched filtering can be used to segment the sEMG signal to identify various stages of the actions being performed. However, matched filtering requires multiple observations to generate appropriate templates for each movement. When many movements are to be detected, such as transitions between various isometric contractions in myoelectric control, the excessive amount of template data prevents the use of matched filtering for sEMG segmentation. This work explores the application of prevalent time-series predictive techniques to identify transitions between active contractions in sEMG signals. METHODS: The sEMG signal from

one subject is collected using 8 electrodes evenly spaced surrounding the forearm of the dominant hand. The subject performed every permutation of transition between 7 classes of position: no movement/rest, wrist pronation, wrist supination, wrist flexion, wrist extension, chuck grip, and hand open. This process was repeated for 5 trials. Leap Motion Capture was synchronously collected, with the transitions being manually identified through observation of the palm normal and sphere radius measurements. The mean absolute value and wavelength features are extracted from all sEMG channels. A traditional threshold-based technique was applied by computing the Teager-Kaiser energy operator (TKEO) and applying a threshold based on the standard deviation observed in the signal. Two predictive models were developed to leverage temporal information in the detection of these transitions. The first is a CNN-based auto-encoder, while the second is an LSTM-based auto-encoder. A VAR-based model was explored, but computational load prohibited its use. RESULTS: The TKEO-based threshold resulted in 54 of the possible 84 transitions being detected with mean errors of 0.53 and 0.54 sec respectively in identifying the beginning and end of the transition. The CNN-based predictive model resulted in 56 transitions being detected with average detection errors of 0.58 and 0.31. The LSTM-based predictive model resulted in 50 transitions being detected, with mean errors of 0.57 and 0.32. CONCLUSIONS: The implementation of time-series techniques improved the precision with which the end of transitions is detected. However, the reliability to detect transitions is not sufficient for automatic segmentation of sEMG signals. All results were highly-dependent on feature selection, signal preprocessing, and model architecture. Therefore, further tuning of the models may prove beneficial.

P3-B-7 ARTHROGENIC MUSCLE INHIBITION BIOMARKER EXTRACTION USING EXPLAINABLE MACHINE LEARNING TECHNIQUES.

Macarena Soldan[1], Rony Silvestre[1]
[1]MEDS Clinic

BACKGROUND AND AIM: Muscle atrophy is a common complication in patients after ACL surgery. To date, it is unknown if there are clinical variables that allow us to classify patients who present muscle atrophy from those who do not, in addition, it is unknown if there are clinical markers for muscle atrophy. The aim of this study is to, Identify and characterize biomarkers in the clinical variables measured that are associated with muscle atrophy through explainable machine learning (ML) techniques. METHODS: Clinical variables from 150 patients who underwent ACL reconstruction will be extracted from a clinical database along with sociodemographic information. These clinical variables correspond to different routine measurements take throughout the rehabilitation process. The data will be labelled in order to identify which patients developed muscle atrophy and which ones didn't, these labels will be extracted from the clinical chart. Finally, the ML techniques will be implemented, explainers will be used to extract the most important features for the classification task. EXPECTED RESULTS: It is expected that the classification task gets an accuracy of at least 70% in one of the models. It is also expected that the explainers can extract the most important features for the classification task, these features could be used as preventive markers for muscle atrophy. To date, we have been able to find statistical meaningful differences between the control group and the ACLR group.

C - Biomechanics

P3-C-8 Shoulder muscle synergy influenced by filter type of EMG during high-speed overhead stroke

Hamidreza Barnamehei[1], Abolfazl Panahi[2]
[1]Washington State University, [2]Science and Research branch, Islamic Azad University

The goal of the current attempt was to examine how the filter type of EMG signals influences shoulder muscle synergy during the badminton overhead stroke. Muscle synergy analysis has been used to analyzed muscle coordination for various applications such as ergonomics, sports motions, and robotics sciences. Understanding fundamental motor coordination of high-speed overhead tasks such as badminton overhead stroke (BOS) enables us to apply the information comprehensively in sports or biomedical sciences. Twenty professional badminton athletes (61.3±8.3 kg, 172±6.8 cm, 29.5±8.5 years) executed the BOS. Ten Vicon motion captures were used to record the kinematics data for kinematics interpretation. EMG activity of the anterior deltoid, middle deltoid, posterior deltoid, infraspinatus, upper pectoralis major, middle pectoralis major, lower pectoralis major, latissimus dorsi, triceps lateral, triceps medial, biceps brachii, upper trapezius, middle trapezius, and lower trapezius muscles were recorded. The EMG data were full-wave rectified and filtered by a low-pass filter (Butterworth, 4th order) with five different cut-off frequencies ranging from 0.5 to 20 Hz was used: f=0.5 Hz, f=1 Hz, f=5 Hz, f=10 Hz, f=20 Hz. An NMF (Non-negative matrix factorization) was applied to extract muscle synergy from EMG data. Based on the results, by increasing the cut-off frequency values, the global VAF was decreased. These results reveal that filter type of EMG data can influence muscle synergy analysis. This study provided valuable information about the relationship between cut-off frequency value and muscle synergy analysis.

P3-C-9 Walking with a passive exoskeleton during everyday obstacles

Cristina Pirscoveanu[1], Mads Pedersen[1], Jacob Hansen[1], Pascal Madeleine[1]
[1]Aalborg University

Walking with a passive exoskeleton during everyday obstacles C.I. Pirscoveanu*, M. Pedersen, J. Hansen, P. Madeleine Sport Sciences - Performance and Technology, Department of Health Science and Technology, Aalborg University, 9220 Aalborg, Denmark, *Ph.D. student civ@hst.aau.dk INTRODUCTION: Avoiding everyday tripping obstacles while wearing an exoskeleton has been shown not to hinder the ability of the wearer to safely clear the obstacle (1). Moreover, exoskeletons have shown increased step lengths and walking speed when worn in laboratory setups (1,2). However, walking obstacles and tripping hazards are often outdoor situations. Therefore, the aim of this study was to investigate certain outdoor walking hazards while wearing a passive assistive hip exoskeleton on hip joint kinematics. METHODS: Eleven healthy male adults (25.2 ± 2.8 years, 185.4 ± 5.9 cm, 98.8 ± 15.3 kg) walked with an exoskeleton (EXO) and without the device (noEXO) during three outdoor obstacle conditions: while stepping up a sidewalk (C1), while stepping over a pothole (C2) and on a flat walking surface. The exoskeleton used was a bilateral hip assistive exoskeleton (IMASEN, Aichi, Japan). All three walking conditions were in the same general area and had the same walking surface. The sidewalk had a height of 11 cm and the pothole had a gap of 30 cm. The participants were instructed to walk at their self-selected speed and 5 trials were collected for each walking and exoskeleton condition. The walking and exoskeleton conditions were randomized. Three-dimensional hip joint kinematic data and were collected bilaterally using Xsens MTw Awinda at a frequency of 100Hz. Prior to data collection, all participants were allowed to familiarize themselves with the obstacles, exoskeleton and Xsens suit. The walking data was reduced to include: one step prior to the obstacle, one step clearing the obstacle and one step over per trial. A paired sample t-test was conducted (p-value <0.05, inferred significance) for the hip joint range of motion (ROM) angle in 3D. RESULTS: The left hip joint ROM angle showed no significant changes between the EXO and noEXO in any of the obstacle conditions during flexion/extension, abduction/adduction and internal/external rotation. However, the right hip joint

ROM angle showed a 5.6% significant decrease (EXO: 8.42 ± 1.42°, noEXo: 8.92 ± 1.89°, p = 0.038) in hip abduction while wearing the exoskeleton during the step over obstacle. No other significant differences were seen on the right hip joint ROM angle. CONCLUSION: The present findings revealed a small decrease in the right hip abduction ROM angle when healthy adults tried to step over a pothole, which can be justified by the fact that all the participants were right leg dominant and that the right leg was used to clear the obstacle. Furthermore, the lack of other statistical differences indicates that wearing a passive assistive hip exoskeleton does not hinder gait kinematics on healthy male adults suggesting that such devices may not increase the risk of tripping. (1) Zhang Z et al. Sensors 20(20): 5844, 2020. (2) Muro-de-la-Herran A. et al. Sensors 14(2):3362-94, 2014.

P3-C-10 Variability and stability of triceps surae M-wave and ankle joint motion during walking, running, and hopping

Michelle McLeod[1], Roland Cote[1], Bridgette Pouliot[1], Aiko Thompson[1]
[1]*Medical University of South Carolina*

BACKGROUND AND AIM: During cyclical motion, such as walking and jumping, rapid and dynamic changes in muscle length and joint motion occur, and likely affect effectiveness of peripheral nerve stimulation and EMG recording. For example, the amplitude of soleus maximum M-wave (Mmax) is reported to vary across the step cycle during walking, suggesting that Mmax variability be considered in EMG amplitude and reflex size assessment. However, there is no established guideline as to how much stimulation should be given to ensure the achievement of Mmax at each part of the step cycle. Thus, to understand the extent and pattern of Mmax variation over the movement cycle, we examined the triceps surae recruitment curves during walking, running, and two-leg vertical hopping. METHODS: In healthy adults (N=13, 7F, age 20-45yrs), the soleus, medial and lateral gastrocnemius recruitment curves were obtained by tibial nerve stimulation. Single 1-ms square pulse stimulation was delivered during standing, walking, running, and hopping. Stimulus intensities ranged from the H-reflex threshold to above the Mmax level. For all cycles the inter-stimulus interval was set to have at least one unstimulated cycle between stimuli, and several hundred trials were obtained. For walking data, the complete step cycle was divided into 12 bins of equal duration. For running and hopping data, the complete cycle was divided into 8 bins. M-wave recruitment curve was constructed for each bin. RESULTS: The results show that Mmax varies within mean±20% range over all movement cycles; mean Mmax values across movement cycles are slightly larger than standing Mmax. While the extent of variation is similar, the variation pattern over the movement cycle is not consistent across different individuals and muscles. Notably, the stimulus intensity needed to achieve Mmax markedly differs across the cycle, suggesting that a fixed relative intensity (e.g.,1.5 X resting Mmax) would not guarantee the achievement of Mmax across the entire movement cycle in different individuals and muscles. When evaluating the effect of stimulus intensity on ankle joint angle, the highest stimulation used to achieve Mmax resulted in 2.2±2.6degrees (range:-3.3 to 6.5) more dorsiflexion (DF) than at the lowest intensity during the swing phase of walking. There were no differences in motion across the walking cycle between the lowest and moderate stimulus intensities. Ankle motion during running was highly variable between individuals.During the hopping flight phase the ankle had as much as 6.8±3.7 more DF at a moderate stimulus intensity versus the lowest, and as much as 7.4±4.3 more DF at the highest stimulus intensity compared to the lowest. CONCLUSIONS: The present study shows that ankle motion may be impacted in a functionally significant way with higher stimulus intensities. Consideration should be taken to determine if the delivery of Mmax eliciting stimulation is always necessary during dynamic motion, as it may influence locomotion kinematics. Support: NIH NICHD P2C HD086844-01 (Kautz)

P3-C-11 Relationship between shear elastic modulus and passive muscle force in human hamstring muscles: a Thiel soft-embalmed cadaver study

Gakuto Nakao[1], Keigo Taniguchi[1], Takuya Kato[1], Taiki Kodesho[1], Yu Yokoyama[1], Yuhei Saito[1], Masaki Katayose[1]
[1]Sapporo Medical University

BACKGROUND AND AIM: Hamstring strains are caused by rapid extensive contractions or overstretching of the hamstring muscle group, resulting in high mechanical stress. Two specific types of hamstring injuries, based on the injury mechanism, have been described: (1) sprint-type injuries that occur during high-speed running and mainly involve the biceps femoris long head (BFlh) and (2) stretch-type injuries that occur during extensive lengthening of the hamstrings and often involve the free proximal tendon of the semimembranosus (SM). The mechanical properties of each hamstring muscle can be determined, noninvasively, using shear wave elastography (SWE), an ultrasound imaging technique that quantifies Young's modulus and shear modulus. The strong linear relationship between muscle shear modulus and passive muscle force obtained using SWE, indicates that the mechanical stresses associated with individual muscle stretching can be estimated. However, the relationship between shear modulus and passive force in individual hamstring muscles is not established. The purpose of this study was therefore to determine this relationship using a Thiel soft-embalmed cadaver. METHODS: BFlh, semitendinosus (ST), and SM muscles were dissected from nine cadavers and fixed to a self-made mechanical testing machine. The proximal and distal hamstrings tendons were separately immobilized using the clamps of a pulley device. Calibrated weights (0−1800 g) were applied gradually, in 150 g increments, to the distal tendon via a pulley system. The shear modulus was measured at points located at 25% (proximal), 50% (central), and 75% (distal) of the total muscle length for each loading condition using SWE. The shear modulus vs. passive load relationship for each tested muscle region was analyzed using a least-squares regression line. The within-session intra-rater reliability of the shear modulus for each muscle was assessed using the intraclass correlation coefficient (ICC [1, 1]). RESULTS: There was a linear correlation between the shear modulus and passive muscle force for all the hamstring muscles in each region ($P<0.01$). The coefficients of determination (R2) were as follows: BFlh (proximal; R2= 0.984±0.011, central; R2= 0.985±0.007, distal; R2= 0.977±0.018), ST (proximal; R2= 0.970±0.022, central; R2= 0.956±0.036, distal; R2= 0.959±0.035), and SM (proximal; R2= 0.975±0.029, central; R2= 0.979±0.019, distal; R2 = 0.979±0.016). The ICC (1, 1) of the within-session intra-rater reliability ranged from 0.974 to 0.996 for all the muscles. CONCLUSIONS: The high coefficients of determination of the individual hamstring muscles indicate that muscle elasticity accounts for more than 95% of the change in passive muscle force. This suggests that SWE can be used to estimate the mechanical stress of each hamstring muscle regardless of the portion of the muscle.

P3-C-12 Effect of Load and Arm Rotation on Scapular Initial Position, Kinematics, and 3D Scapulohumeral Rhythm

James Michaud[1], Spencer Nehls[1], Traci Bush[1], Vassilios Vardaxis[1]
[1]Des Moines University

INTRODUCTION: Shoulder movement coordination in symptomatic patients has traditionally been assessed using scapulohumeral rhythm (SHR). The SHR is narrowly viewed as the ratio of glenohumeral

(GH) to scapulothoracic (ST) joint contribution in the plane of arm elevation. The current accepted ratio of SHR is 2:1 (GH:ST) over the entire range of arm elevation, with the trunk in the upright posture, the palm on the plane of elevation and the thumb up (TU; full can). However, shoulder rehabilitation protocols, activities of daily living, and occupational tasks induce a variety of conditions which may affect shoulder kinematics, coordination, and SHR. This study aims to investigate the influence of load and arm rotation on scapulothoracic initial position, scapular kinematics, and the 3D-SHR during arm elevations in the frontal, sagittal, and scapular planes. METHODS: Twenty right-handed male adults performed 120° arm elevations on 3 planes with 1, 3, & 5-pound hand-held load, as well as, with the thumb up and thumb down (TD; empty can). A motion analysis system with 10-cameras (Motion Analysis Corp.) running at 120 Hz was used to capture 3D data of reflective markers attached to the upper-limb and torso. Euler angles were used to compute scapulothoracic, glenohumeral, and thoracohumeral 3D initial position and kinematics during each task, per ISB recommendations. The 3D-SHR was assessed as the slope of the linear regression best-fit line of the 3D scapulothoracic angle and glenohumeral arm elevation between 15° and 105° of arm thoracohumeral elevation. ANOVA repeated measures and dependent t-tests were used to test for significant differences between conditions, at $\alpha = 0.05$. RESULTS/DISCUSION: The initial (starting position) showed significantly greater humeral abduction and greater scapular upward rotation, posterior tilt, and internal rotation for the empty-can condition relative to the torso, with greater difference for the sagittal (6.1±0.2°) vs. the frontal (3.1±0.8°) plane. The 3D scapulothoracic kinematics during arm elevation showed significantly lower posterior tilt (7.8±1.2°) and greater external rotation (5.2±1.8°) difference for the empty-can condition, resulting in a 7.0±1.8° 3D angle difference across all 3 planes increasing in magnitude from sagittal to frontal. The 3D-SHR during arm elevation was consistent across all load conditions and it was found significantly greater for the empty-can (2.8±0.3) vs. the full-can (2.3±0.1) condition, with the greater difference found for the sagittal plane. Neither the scapular initial position nor the 3D scapulothoracic kinematics were significantly affected by load. CONCLUSION: When measuring scapular initial position, 3D kinematics, and 3D-SHR across arm elevation tasks, arm rotation (full-can vs. empty-can) has a significant effect while load showed no effect. Evaluation of shoulder overall position and movement under various conditions is necessary for the creation of a normal model for shoulder function. Future studies can use these findings when determining the effect of pathology on scapular position and movement.

E – Clinical Neurophysiology

P3-E-13 Correlation between functional and electrophysiological measures in COVID-19 post-intensive care syndrome patients

Marco Benedini[1], Marta Cogliati[1], Tea Lulic[1], Kelvin Jones[2], Nicola Latronico[1], Simone Piva[1], Claudio Orizio[1], Francesco Negro[1]
[1]University of Brescia, [2]University of Alberta

BACKGROUND AND AIM: Intensive care unit (ICU) stay for COVID-19 led patients to acquire a Post-Intensive Care Syndrome (PICS) characterized by prolonged fatigue and muscle weakness which can be observed over several months or years after the discharge. The assessment of neuromuscular damage and fatigue is complex in these patients due to the physical, mental, and cognitive impairments caused by the disease and hospitalization. Thus, the assessment involves the combined analysis of biological parameters and biomechanical factors related to muscle activity. This study aims to evaluate the correlation between functional variables i.e. the maximal voluntary contraction (MVC), and electrophysiological variables i.e. the compound muscles action potential (CMAP) and the motor unit

number index (MUNIX) in COVID-19 PICS patients. METHODS: Fifty-one COVID-19 patients (37 males, 14 females) were recruited from the ICU of Spedali Civili Hospital in Brescia. The group underwent a follow-up assessment at 3-, 6- and 12-months following ICU discharge. The investigated muscle was the tibialis anterior (TA). The experiment included a stimulation protocol and a voluntary protocol. During the stimulation protocol, the CMAP was estimated by stimulating the common peroneal nerve (CPN) at maximum amplitude with two active electrodes positioned behind the head of the fibula. During the voluntary protocol, after maximal voluntary contraction (MVC) estimation, patients performed a series of submaximal isometric foot dorsiflexions at 30, 50, and 70% MVC. The MUNIX was calculated using the CMAP, and the surface electromyographic interference patterns (SIP) recorded during the isometric contractions [1]. The CMAP and the SIP were derived from the HD-sEMG signals recorded from the TA with a 64-channel matrix. RESULTS: The mean variations in MVC between 3- and 6-months follow-up (10.75%) and between 6- and 12-months (16%) following COVID-19 ICU discharge were paralleled by changes in CMAP for the same period (+10.85% at 6 compared to 3 months, and +1.09% at 12 compared to 6 months). The linear regression analysis showed a moderate correlation between MVC and CMAP ($R2= 0.20$; $p<0.001$) and between MVC and MUNIX ($R2= 0.18$; $p<0.001$). CONCLUSIONS: The MVC was significantly correlated with CMAP and MUNIX estimations. The correlation between functional and electrophysiological variables allows longitudinal assessment of the neuromuscular damage in COVID-19 PICS individuals and opens the possibility for an early clinical evaluation of non-collaborating patients admitted to the ICU and their subsequent follow-up. [1] Nandedkar SD, Nandedkar DS, Barkhaus PE, Stalberg EV. Motor unit number index (MUNIX). IEEE Trans Biomed Eng. 2004 Dec;51(12):2209-11. doi: 10.1109/TBME.2004.834281. PMID: 15605872.

P3-E-14 Immediate effects of lower limb electrical stimulation and cycling on cortical activities and functional performance in individuals with stroke

Chia Fang Chiang[1], Li Wei Chou[1], Liang Hsuan Lu[2], Shang Lin Chiang[2]
[1]National Yang Ming Chiao Tung University, [2]Tri-Service General Hospital

BACKGROUND AND AIM: Gait asymmetry are often observed in stroke survivors. Repetitive motor training and sensory input are essential for brain reorganization and motor recovery after stroke. Previous studies have demonstrated that electrical stimulation (ES) is beneficial for promoting neuroplasticity and facilitating poststroke motor recovery, and combing ES and cycling training has potential on further promoting post stroke motor recovery. However, whether combining ES and cycling could improve gait symmetry in stroke survivors remains unknown. Therefore, the aim of this study is to investigate the immediate effects of ES combined cycling on gait symmetry and neurophysiological changes in stroke survivors, and to determine the correlation between changes of the neurophysiological data and functional outcomes. METHODS: Sub-acute stroke patients are recruited and assigned to either ES combined cycling group or sham-ES combined cycling group. Each group receives 30 min cycling with consistent ES or sham-ES. EEG from the LE area of sensorimotor cortex (Cz) and EMG of quadriceps and tibialis anterior muscles are recorded simultaneously before, during and after the intervention. The functional outcomes include self-selected and fast gait speed(m/s), cadence(steps/min), stride/step length(m) of both legs, gait symmetry index. Two way mixed-model ANOVA is used to assess all outcome difference across groups and different time points. Post-hoc comparison with Bonferroni correction is used to examine the between-group and within-group differences for all outcome measures. Pearson correlation test is used to assess changes between neurophysiological data and functional outcomes. The α level is set at 0.05. RESULTS: 9 stroke subjects are recruited so far. The EEG power spectrum density (PSD) of Cz increased average 72% in β band from 0.247 ± 0.08 to 0.264 ± 0.08, and increased average 24% in γ band from 0.145 ± 0.07 to 0.18 ± 0.12 during fast-speed walking in ES group. The PSD of Cz EEG increased average 13% in β band from 0.298 ± 0.07 to 0.338 ± 0.09, and decreased average 2% in γ band from 0.117 ± 0.03 to 0.113 ± 0.09 during fast-speed walking in sham-ES group. The step length symmetry ratio increased from 0.91 ± 0.16 to 0.98 ± 0.18, and the stride length symmetry ratio increased from 1.0 ± 0.11 to 1.01 ± 0.05 during fast-speed walking. Significant relationship was observed between the increase in stride length symmetry ratio and decrease in the PSD in γ band during fast-speed walking (r = 0.704). Our preliminary results suggested that ES combined with cycling immediately improved gait symmetry in people with stroke, and the improvement in gait symmetry was related to desynchronization in EEG gamma band. CONCLUSIONS: We plan to complete the data collection and present the overall results at the ISEK 2022 conference.

P3-E-16 Effects of low back pain on postural control under different conditions of tendon vibration and muscle fatigue

William Gelinas[1], Louis-David Beaulieu[1], Richard Preuss[2], Hugo Massé-Alarie[3], Leonardo Vieira Neto[4], Jérémie Désilets-Paquet[1], Elisabeth Gauthier-Levesque[1], Florence Lamontagne[1], Marie-Pier Lemay[1], Véronique Tremblay[1], Rubens A. da Silva[1]
[1]Université du Québec à Chicoutimi, [2]McGill University, [3]Université Laval, [4]CIUSSS-SLSJ

Background: An altered processing of movement-related afferents from the spine and increased fatiguability of trunk muscles have been documented in the presence of low back pain (LBP). These problems might lead to higher risks of back injury and falls, but research having studied the link between fatigue, sensory processing, and postural control in the presence of LBP is limited, especially in aging or retired workers which are at higher risk of postural instability. The aim of the present study was to assess the influence of LBP and fatigue of erector spinae muscles on a bipedal postural task including various visual/proprioceptive manipulations in adults. Method: Eleven healthy adults (age 29�5 yrs), and twelve with LBP (age 36�8 yrs), were tested in bipedal standing on a force platform under three eyes-closed experimental conditions (3 trials of 30 seconds per condition): 1) without vibration, 2) with bilateral vibration of the Achilles tendons, and 3) bilateral vibration of lumbar muscles (multifidus). Testing was performed immediately before and after a fatiguing Roman chair exercise protocol targeting the trunk extensor muscles. Clinical status (participants with LBP), endurance time (Roman chair), and center of pressure (COP) measurements were computed (COP area ellipse (cm2), amplitude (cm), velocity (cm/s) and frequency of oscillation (Hz) in the antero-posterior and medio-lateral directions). Results: No difference ($p > 0.05$) was found between participants with and without LBP for endurance and COP variables. No significant interaction was also observed between the main factors (Groups x vibration conditions x fatigue). Vibration of ankle tendons significantly increased ($p < 0.01$) COP variables (higher COP values for poor postural control), whereas vibration of lumbar muscles only increased medio-lateral oscillation frequency. Participants with LBP reported low pain intensity (2/10) and disability. Conclusion: The results of this study showed no significant difference in postural control between groups during a simple balance task under sensory manipulation. Bilateral Achilles tendon vibration affected the COP measures for both groups, regardless of the state of fatigue of the trunk extensor muscles. These results show no evidence of an altered sensory coding, relevant for postural control, in the presence of LBP and/or trunk muscle fatigue, at least in younger adults reporting minimal pain and disability. Further research is required for individuals with greater pain and disability and for older adults.

P3-G-17 **Correlation between motor unit synchronization estimated through intramuscular and surface EMG in the vastus medialis obliquus: a validation study**

Corrado Cescon[1], Ausilia Vistarini[2], Caterina Pisegna[3], Beatrice Vannini[3], Cristian Zampella[2], Luca Calanni[2], Emiliano Soldini[1], Giuseppe D'Antona[2]
[1]2rLab, University of Applied Sciences and Arts of southern Switzerland, [2]University of Pavia, [3]Civilian Hospital of Voghera

BACKGROUND AND AIMS: During fatiguing contractions synchronization between the firing times of simultaneously active motor units (MUs) is generally assumed to increase. Recent studies have added weight to this hypothesis using indirect estimates of synchronization derived from surface electromyographic (EMG) interference signals, such as fractal dimension (FD), sub-band skewness or multi-fractal detrended fluctuation analysis. However, previous studies using intramuscular EMG (iEMG) have reported no change in MU synchronization during fatigue. Therefore, the aim of this study was to investigate the correlation between MU synchronization detected through intramuscular EMG and the FD of the sEMG signal in the vastus medialis muscle during isometric fatiguing contractions METHODS: 16 healthy men (30±9 years) volunteered to participate in the study. Participants performed two maximal voluntary contractions (MVC) followed by a 5% MVC of 5 min, and immediately afterwards a third MVC. EMG signals were detected (a) using a couple of fine-wire electrodes and (b) two couples of bipolar surface electrodes from the left vastus medialis obliquus. The iEMG signal was fully decomposed using EMGLAB through the Montreal algorithm. Synchronization of MU firings was then calculated using the Synch Index as proposed by De Luca et al. (1993) on cross-correlation histograms. Initial value of FD of the EMG signal was calculated. Correlation between the Synch Index and FD was investigated using Spearman correlation coefficient. RESULTS: A statistically significant moderate correlation was found between the Synch Index and FD (rho= -0.3; $p<0.05$) (Figure 1). CONCLUSIONS: The results suggest that during fatiguing isometric contractions, changes in the FD of the sEMG signal may be related to an increase in MU synchronization. Therefore, FD appears to be a valid alternative to the use of intramuscular EMG for the study of MU synchronization. Figure 1: Correlation analysis between the Synch Index (intramuscular EMG) and the fractal dimension (FD) of the sEMG signal. The two indices were calculated during the initial and final 50 s of the 5% MVC isometric contraction of the vastus medialis obliquus muscle (rho = -0.3, p=0.18).

P3-G-18 **Energy consumption during treadmill walking in adults with cerebral palsy as compared to neurologically intact adults**

Christian Forman[1], Christian Forman[2], Christian Svane[2], Jens Bo Nielsen[2], Jakob Lorentzen[1]
[1]University of Copenhagen, [2]Elsass Foundation

BACKGROUND AND AIM: Adults with cerebral palsy (CP) have reduced central motor control and peripheral soft tissue changes due to their central motor lesion. We hypothesize that these neuromuscular impairments affect postural control and movement energy efficiency of daily activities such as gait, and that reduced energy efficiency could be a factor in the high prevalence of fatigue in adults with CP. We therefore aimed to measure energy consumption during gait in adults with CP and how it is affected by the neuromuscular changes following the central motor lesion. METHODS: Twenty adults with CP and twenty age- and sex matched neurologically intact (NI) adults was recruited to undergo measurements of oxygen consumption, electromyography of the lower leg muscles, and gait kinematics obtained by Qualisys movement tracking during treadmill walking at their self-selected pace.

We calculated an energy efficiency index from the oxygen consumption and gait speed and compared this to the step-to-step variation and postural symmetry. Additionally, ultrasound- and stiffness measurements of the plantar flexors was performed to assess the effect of muscle composition on gait pattern and the everyday experience of fatigue was assessed by the Multidimensional Fatigue Inventory questionnaire. In this way, we analyzed how specific movement patterns associated with efficiency of energy. NI adults walked at both 50% and 25% of their self-selected gait speed to see how energy efficiency was affected by gait speed. Maximal oxygen uptake was measured from an incremental VO2-max test on a stationary exercise bike. Maximal oxygen uptake was used to calculate the relative metabolic load that everyday activities, such as gait, require when living with CP. Electromyography was used to test whether the muscles of the lower limb exhibit fatigue during the gait test and how the fatigue affects gait posture. RESULTS: We found reduced energy efficiency during toe gait and during slower walking speeds. Many adults with CP walk on toes, at a slower pace than NI adults and with asymmetric and variable gait patterns, leading to a higher energy expenditure during everyday gait. NI adults did not show fatigue-related changes in muscle activity during walking, but CP adults fatigue faster due to their different muscle composition, further decreasing energy efficiency. CONCLUSIONS: Our study provides indications about how neuromuscular impairments in adults with CP affects energy efficiency during everyday movement and how this might be an important factor for the daily experience of fatigue.

P3-G-19 The effects of handedness on muscle activation during a repetitive overhead fatiguing task

Erika Renda[1], Samuel Lamanuzzi[1], Julie Côté[1]
[1]*McGill University*

BACKGROUND AND AIM: The long-term preferred use of the dominant arm can lead to changes in muscle fibre composition with more type 1, slow twitch fibers in the main arm agonists (Fugl-Meyer et al., 1982). How this preferred limb use may affect chronic adaptations and fatiguability is unclear. Most studies conducted on hand dominance investigated hand muscles. No study to our knowledge has examined the effect of handedness on fatigue of multiple shoulder muscles during a repetitive overhead task. METHODS: Thirty right-handed healthy adults (15 males) are recruited to complete two sessions of a fatiguing task: one performed with the dominant arm, and one with the non-dominant arm (random order). Participants filled out the 10-item Edinburgh Handedness Inventory allowing the calculation of a Laterality Quotient. Surface electromyography (EMG) electrodes were placed on 11 upper body muscles. Intramuscular EMG electrodes were placed on supraspinatus, infraspinatus and subscapularis. Before the task, participants performed Maximal Voluntary Isometric Contractions (MVIC) for each muscle. The fatiguing task consisted of repetitively flexing the shoulder from 90 to 135 degrees at 1 Hz by aligning the dot of a laser attached to the upper arm with targets placed on the wall in front, until exhaustion or missing the target 3 consecutive times. The first and last 30 s of the task were classified as Non-Fatigued (NF) and Fatigued-Terminal (FT). The NF and FT data was partitioned into 15 upward and 15 downward movements. For each movement, Root-mean-square (RMS) values were calculated over 15, 1s non-overlapping windows. The average of the 15 RMS values of the upward movement were normalized to the max RMS value of the MVICs. A two-way repeated measures ANOVA was used to assess the main and interaction effects of arm (dominant, non-dominant) and fatigue (NF, FT) on RMS. T-test was used to evaluate the effect of arm on time to failure. Pearson correlation was used to test the relationship between Laterality Quotient and differences (Dominant - Non-dominant) in bilateral muscle activation.

RESULTS: Preliminary results (N = 5) show no significant arm × fatigue interaction effects. There was main arm effect on upper trapezius (UT) RMS ($p = .026$), which was more activated during the experimental task on the non-dominant arm. Results showed main effects of fatigue on RMS of cervical erector spinae ($p = .038$), middle deltoid ($p = .040$), supraspinatus ($p = .040$) and UT ($p = .021$). No effect of arm on time to failure was determined ($p = .43$). Pearson correlation showed that as the strength of right-handed increased, right side dominance in AD EMG decreases ($r = -0.99$, $p = .009$). CONCLUSION: Results will help determine the extent to which arm symmetry should be assumed during upper limb fatiguing tasks, in healthy workers as well as those recovering from an injury. Fugl-Meyer AR, et al. (1982). Acta Physiol. Scand. 114: 277-81

P3-G-20 **Between-day reliability of common muscle fatigue measures**

Michael Watterworth[1], Jeffrey Graham[1], Nicholas La Delfa[1]
[1]*Ontario Tech University*

BACKGROUND AND AIM: Researchers in ergonomics often examine neuromuscular fatigue responses across a range of physical exposures to determine acceptable limits and minimize risk of injury. However, due to the nature of fatigue research, multiple experimental sessions are often collected on different days to ensure participants have sufficient time to recover to 'baseline' levels. As such, there is an assumption that any between-day change in fatigue metrics (e.g. myoelectric, strength, etc.) are solely due to the experimental manipulations, with minimal day-to-day variability obscuring results. Subsequently, the purpose of this study was to examine the reliability of EMG- and strength-based fatigue measures across multiple testing days. METHODS: Twenty participants (10M, 10F) were recruited from a convenience sample of university students. On three different days, participants performed identical cyclic fatigue protocols consisting of isometric elbow flexion for 60-minutes. Surface electromyography (EMG) of the biceps brachii was recorded, differentially amplified, and RMS filtered. Mean power frequency (MnPF) was computed using a fast Fourier transform. aEMG, MnPF, and force values during maximum voluntary contractions (MVC) were then normalized to baseline values. Using these three normalized fatigue measures, slopes were calculated to determine the rate of change for each fatigue measure over each day's fatigue protocol. To determine relative between-day reliability, Intraclass Correlation Coefficient (ICC) estimates and their 95% confidence intervals were calculated for all dependent measures based on a single-rating, absolute-agreement, 2-way mixed-effects model. To determine absolute between-day reliability, two measures were calculated: Standard error of measure (SEM) and minimum difference to be considered real (MD95). RESULTS: Baseline MVC demonstrated excellent between-day reliability (ICC: .96 ±.03) with good absolute reliability (SEM: 5.10%, MD95: 14.1%). In general, the absolute reliability of all slope-based fatigue measures was low. However, some had promising relative reliability. Namely, MVC Slope, which demonstrated poor to good reliability (ICC: .67 ±.17), and MnPF Slope, which had moderate to good between-day reliability (ICC: .75 ±.14) (Table 1). CONCLUSIONS: Caution is recommended when utilizing slope-based fatigue measures across multiple sessions. Previous research suggests using normalized median power frequency and amplitude of sEMG from the final 5 seconds of sustained contractions yields higher relative and absolute reliability than that of their respective slopes. We propose subjective measures of fatigue should also be included in future fatigue research, alongside objective measures, to provide a more comprehensive investigation of fatigue across multiple sessions.

P3-G-21 **Neuromuscular fatigue is dependent on the amount of active muscle mass in cycling tasks across discrete intensity domains**

Jenny Zhang[1], Danilo Iannetta[1], Saied Aboodarda[1]
[1]*University of Calgary*

BACKGROUND AND AIM: The ability to sustain exercise in different intensity-durations is modulated by neuromuscular (NM) fatigue, a task-dependent phenomenon which relies on the amount of active muscle mass engaged in the task. We hypothesized that regardless of intensity, a larger exercising muscle mass would result in greater central fatigue due to more ensembled inhibitory feedback from locomotor muscles, whereas smaller active muscle mass would result in greater peripheral fatigue. METHODS: Eleven males (29±4 years) performed counterweighted single-leg (SL) and double-leg (DL) cycling to task failure in moderate (MOD), heavy (HVY), severe (SVR), and extreme (EXT) intensity domains, as characterized by gas exchange threshold, respiratory compensation point, and maximal aerobic capacity from a DL ramp incremental test. SL cycling was performed at 60% of the power output set to the corresponding DL session. NM fatigue, obtained at baseline, immediately upon task failure, and following 1, 4, and 8 min of recovery, was characterized by a 5-s maximal voluntary contraction (MVC) of the dominant knee extensors with superimposed 100 Hz doublets (Db100) and resting Db100, 10 Hz doublets (Db10), and single twitch (QTw). Paired t-tests compared relative changes at task failure between modes (SL vs. DL), while two-way repeated measures ANOVAs with Bonferroni post hoc examined 2 modes at 4 timepoints within each domain. RESULTS: Time to task failure was similar between SL and DL cycling sessions in all domains except EXT, whereby DL lasted longer than SL (p=0.004). MVC force was lower immediately following SL cycling (-42±16%) compared to DL in HVY (-30±18.3%; p=0.011) and SVR (SL:-41±12%; DL:-31±15%; p=0.036) domains. Voluntary activation was lower after SL cycling (-20±15%) than DL (-9±10%; p=0.008) in the HVY domain. QTw was lower after DL cycling in MOD (SL:-2±16%; DL:-13±17%; p=0.033) and after SL cycling in HVY (SL:-31±12%; DL:-22±10%; p=0.007), while no differences between modes were observed in any domains for low-frequency fatigue (Db10:100). No significant differences in any outcomes were observed between modes in EXT. Additionally, for all NM variables, no significant differences were observed between SL and DL cycling at any recovery timepoints. CONCLUSIONS: The extent of central and peripheral fatigue development is influenced by active muscle mass in moderate, heavy, severe, but not extreme, exercise intensities. A smaller active muscle mass leads to faster NM fatigue development at task failure in intensities above gas exchange threshold (HVY and SVR), while peripheral fatigue is a limiting factor in lower intensities (MOD) performed with larger active muscle mass. Despite some differences in fatigue variables immediately upon exercise cessation, active muscle mass did not influence short-term fatigue recovery. Therefore, exercise tolerance in different intensities is muscle mass-dependent.

H – Modelling and Signal Processing

P3-H-23 Kalman filter based motor unit identification in dynamic muscle contractions

Matej Kramberger[1], Ales Holobar[1]
[1]*University of Maribor, Faculty of Electrical Engineering and Computer Science*

BACKGROUND AND AIM: We propose a novel method for predicting and tracking the changes of Motor Unit (MU) filters in MU identification from high-density surface electromyograms (HDEMG), recorded during dynamic biceps brachii (BB) muscle contractions. Deriving from the observation that Motor Unit Action Potentials (MUAPs) changes can be piecewise linearly extrapolated from previously recorded changes [2], we have upgraded the previously published Convolution Kernel Compensation (CKC) [1] method by integrating the Kalman filter (KF) for MU filter updating. METHODS: For objective evaluation of the proposed method, we used simulated HDEMG signals generated using previously recorded

MUAPs of BB muscle during slow dynamic contractions [3], and thus known MU firings. We have simulated ten different muscles, randomly selecting experimentally estimated MUAPs of 252 MUs for each simulated muscle. The CKC method [1] utilizes MUAPs to form the MU filters. As MUAP shapes change during dynamic contractions, so do the MU filters. We studied these changes and demonstrated that they are piecewise linear. Thus, we designed a KF to predict these MU filter changes. We first estimated the MU spike trains on a portion of the HDEMG signal using the CKC method [1]. Then we used the KF to predict the MU filter changes. The updated MU filter was used to estimate the MU firings in the next HDEMG epoch, and the estimated firings were used to correct the MU filter estimations by the KF. RESULTS: The method was tested on ten relatively fast dynamic contractions of BB (10 full concentric and eccentric muscle contractions in 20 s). In noiseless HDEMG signals, KF based MU filter prediction tracked 21.3±1.8 MUs, on average, with an average sensitivity of 95.6±7.0% and precision of 96.5±3.5%. In the same conditions, previously established cyclostationary CKC (csCKC) [3] tracked 18.9±2.0 MUs with the sensitivity of 91.8±12.2% and precision of 94.7±5.1%, on average. In the signals with added 20 dB noise, the proposed method tracked 11.1±1.7 MUs with the sensitivity of 92.3±7.3% and precision of 96.4±3.7%, whereas the csCKC method tracked 10.4±1.2 MUs with the sensitivity of 91.8±8.9% and precision of 93.9±5.4%. CONCLUSIONS: We demonstrated the ability to predict the MU filter changes in dynamic HDEMG signals by upgrading the CKC method [1] with the KF and that the results of the newly proposed method surpass the results of the previously introduced csCKC method [3]. ACKNOWLEDGEMENT: This work was supported by the Slovenian Research Agency (project J2-1731 and Programme funding P2-0041) [1] A. Holobar and D. Zazula, "Multichannel blind source separation using convolution kernel compensation," IEEE Trans. on Signal Process., 55(9):4487-4496, 2007. [2] M. Kramberger and A. Holobar, "On the Prediction of Motor Unit Filter Changes in Blind Source Separation of High-Density Surface Electromyograms During Dynamic Muscle Contractions," IEEE Access, vol. 9, pp. 103533-103540, 2021. [3] V. Glaser, A. Holobar, "Motor Unit Identification from High-Density Surface Electromyograms in Repeated Dynamic Muscle Contractions," IEEE Trans Neural Syst Rehabil Eng. 2019 Jan;27(1):66-75.

I – Motor Control and Motor Learning

P3-I-25 Cutaneous reflexes during walking, jogging, and running

Alan Phipps[1], Aiko Thompson[1]
[1]*Medical University of South Carolina*

BACKGROUND AND AIM: Cutaneous (CUT) reflexes are task-dependently modulated from standing to running (Brain Res. 1993:613:230-238), and the pattern of modulation is nerve-specific during walking (J. Neurophysiol 1997:6:3311-3325). Currently, CUT reflex modulation between different modes of locomotion is not well understood. To examine the effects of speed and mode of locomotion, we measured CUT reflexes in plantar and dorsiflexors during walking, jogging, and running. METHODS: Six individuals with no known neurological conditions participated in this study. CUT reflexes were elicited by stimulating the sural (SRn), superficial peroneal (SPn), and distal tibial nerve (DTn) near the left ankle. For each stimulation, a 5 x 1-ms pulse train (200 Hz) at approximately 1.9 x radiating threshold was delivered while the participant walked at 3 or 4 km/h (slow walk: SW) and 6 or 7 km/h (fast walk: FW), jogged at 6 or 7 km/h, and ran at 9 or 10 km/h. Electromyography was recorded from the soleus (SOL), medial (MG) and lateral gastrocnemius (LG), and tibialis anterior (TA) ipsilateral to the stimulation site. Short (50-80 ms post-stimulus, SLR) and medium (80-120 ms, MLR) latency CUT reflexes were quantified as the difference between stimulated and non-stimulated EMG in the early stance, late stance, and end swing phase for each locomotion condition. RESULTS: During early stance, LG MLR showed significant differences following SRn and DTn conditions. Following SRn, suppression was greater in the run condition (-26% maximum nonstimulated EMG) compared to SW (-6%) and FW (-2%) ($p = 0.006$ and $p = 0.013$, respectively). Following DTn, the LG MLR showed significant reflex reversals going from excitatory in SW (9%) and FW (1%) compared to suppressive during running (-29%) ($p = 0.032$ and $p = 0.025$, respectively). At this phase, following SRn stimulation the TA MLR was significantly more suppressed during FW (-33%) compared to jog (-2%) and run (-3%) ($p = 0.019$ and $p = 0.023$, respectively). The only significant SLR findings were in the SOL and were similar to that seen in the LG MLR following SRn during early stance (i.e., less suppression at SW and FW compared to run). No significant differences were seen during late stance. At the end of swing, the TA MLR showed a significant reflex reversal following DTn stimulation changing from suppression during FW (-7%) to excitation during jogging (36%) ($p = 0.045$). CONCLUSIONS: The speed of locomotion (i.e., SW vs. FW or jog vs. run) did not have a significant impact on CUT reflex modulation; however, the mode of locomotion (i.e., FW vs. jog at the same speed) did. For example, during early stance, TA suppression following SRn stimulation was greater during FW than jog; and at the end of swing, the TA excitation following DTn stimulation was larger during jog than FW. These results suggest that CUT reflexes are not speed but mode dependently modulated during locomotion.

P3-I-26 Neural interaction between the sensorimotor cortex and ankle joint muscles during standing in varying stance widths

Sylmina Alkaff[1], Junichi Ushiyama[1]
[1]*Keio University*

BACKGROUND AND AIM: In natural standing, postural control is mainly regulated by subcortical loop and ankle joint stiffness. Although changes in both cortical and ankle joint muscle activity are known to occur when increased effort is required to maintain posture balance within base-of-support, it is still unclear whether these changes reflect additional cortical control of muscle activity in postural control strategy. As corticomuscular coherence (CMC) indicates the presence of active interaction between the sensorimotor cortex (SMC) and contracting muscle, it can provide clarification on cortical involvement in muscle activity during standing. METHOD: This study examined CMC during standing in different stance widths: feet placed 20-cm apart (apart), feet placed together (narrow), and tandem stances with dominant foot on posterior position (tandem dominant) and non-dominant foot on posterior position (tandem non-dominant). For nineteen subjects, we measured the maximal peak of CMC (CMCmax) between electroencephalograms (EEG) overlying the foot representation area of SMC and electromyograms (EMG) from the tibialis anterior (TA), medial and lateral gastrocnemius (MG and LG), and soleus (SOL) in both legs for each task. We also simultaneously measured center of pressure (COP) and calculated the COP fluctuation by some quantitative measures such as mean distance, standard deviation, mean velocity, and mean frequency. RESULT: All COP parameters were significantly higher in both tandem stances compared to apart and narrow stances, indicating postural instability with decrease in stance width. MG and SOL muscles were active during all stance tasks. In TA and LG, although little to no activity was observed during apart and narrow stance, these muscles were active in tandem stance. The data suggest an adjustment in postural control strategy by activating TA and LG muscles to compensate postural instability during tandem stance. While there was no significant CMC during apart stance, most participants (n=14) showed significant CMC during both tandem stances. On the contrary, only few participants (n=3) showed significant CMC during narrow stance despite larger

COP fluctuation compared to apart stance. All muscles showed higher CMCmax during tandem stances compared to apart and narrow stances. SOL showed significantly higher CMCmax during both tandem stances compared to apart and narrow stance. Although TA also showed significant CMC during both tandem stances, CMCmax was significantly higher when the leg was on posterior position during tandem stance compared to apart and narrow stances. This data suggests different functional role for each muscle during tandem stance. CONCLUSION: Greater CMC during tandem stance suggests an adjustment in postural control strategy due to both postural instability and the unnatural leg position of the stance by modulating cortical control of muscle activity depending on functional role of the muscle.

P3-I-27 Effect of a complex locomotor task on corticospinal excitability and muscle coordination

Yosra Cherni[1], Laurent Bouyer[2], Catherine Mercier[2]
[1]University Laval/Cirris, [2]Université Laval / cirris

Introduction: Locomotor impairments, and particularly the presence of foot drop or tiptoeing, are common in children and adults with cerebral palsy. Studies using transcranial magnetic stimulation (TMS) or using electromyography (EMG) to assess EMG-EMG coherence suggest that impaired functional corticospinal connectivity plays an important role in locomotor impairments. Frequently used locomotor training approaches focus on automatic circuits (via repetitions) and little on voluntary gait control circuits (via precision tasks). This study aims to investigate the effects of a complex locomotor task on corticospinal excitability and EMG-EMG coherence of dorsi-flexors of the ankle as well as muscle synergies. Methods: To date, eight healthy young adults (age=20-25 years) took part in this study. Each participant performed a simple walking task at a comfortable speed and a complex locomotor task (at the same speed; counterbalanced order). The complex task consisted of stepping on virtual targets of varying size and presented at varying intervals (80-120% of the natural step length; on a screen facing the subject) while walking on a treadmill. Corticospinal excitability of the tibialis anterior muscle (TA) was assessed with TMS applied to the motor cortex during walking (30 stimulations/condition:110% of active motor threshold (at 40% of the walking cycle). The activity of the TA was measured using two EMG sensors, positioned at the most proximal and distal part of the TA, in order to assess EMG-EMG coherence in addition to motor evoked potentials. Finally, to assess muscle synergies, supplementary EMG electrodes were placed on rectus femoris, vastus lateralis, semitendinosus, biceps femoris, gastrocnemius medialis and soleus. Preliminary results: Our preliminary results show an increase in corticospinal excitability in all participants during the complex relative to the simple locomotor task. In terms of coherence, it is expected to observe an increased EMG-EMG coherence during the complex task compared to the simple locomotor task. For synergy analysis, it is expected that the task complexity will not affect coordination complexity in terms of number of synergy but rather the strategy of coordination in terms of synergy composition. Conclusion: Overall, an increase in corticospinal excitability was observed during the complex task compared to the simple task. Those results must be confirmed with a larger sample.

P3-I-28 Feedback for the prevention and rehabilitation of musculoskeletal disorders.

Antoine Frasie[1], Charles Plourde[1], Maxime Houry[2], Maxime.T Robert[1], Laurent Bouyer[1], Jean-Sébastien Roy[1]
[1]Université Laval, Cirris, [2]Université de Rouen, Centre d?Études des Transformations des Activités Physiques et Sportives (CETAP

BACKGROUND AND AIM: Work-related musculoskeletal disorders (WRMSDs) continue to cause significant socio-economical burdens. Recent publications have promoted sensorimotor rehabilitation for the management of WRMSDs as sensorimotor disturbance could explain the high prevalence and chronicity rate of WRMSDs. The use of extrinsic feedback has been proposed as a good way to improve sensorimotor control in various contexts. However, there are few systematic reviews on the effectiveness of using extrinsic feedback for WRMSDs. The aim was to investigate the effect of extrinsic feedback on sensorimotor control of individuals with and without WRMSD during work tasks was performed. METHODS: A systematic review of five databases (CINAHL, Embase, Ergonomics Abstract, PsycInfo, PubMed) was performed. Two independent reviewers screened the potential articles, performed data extraction, and evaluated the risk of bias of included studies. Studies with various designs assessing the effects of extrinsic feedback during work tasks in the context of prevention and rehabilitation of WRMSDs were included. Sensorimotor control (e.g. kinematic and kinetic analysis) during the work task was used as the primary outcome. RESULTS: Twenty-nine studies were included, for a total sample of 2545 participants (including 445 with WRMSD) who performed work-related tasks in the workplace (17 studies) or in controlled environments (e.g., research laboratory; 12 studies). Sensorimotor control was mainly objectified using surface electromyography (n=17), inertial measurement units (n=7) and 3D motion analysis systems (n=8). The source (e.g. various sensors, ergonomic counseling), modality (audio, tactile, visual, mixed) and frequency (continuous, intermittent, faded, final) of the extrinsic feedback were heterogenous. The use of extrinsic feedback was found to be effective to improve sensorimotor control in controlled environments for short-term prevention (moderate evidence) and for the rehabilitation of WRMSDs (limited evidence). In the workplace there was conflicting evidence for prevention and limited evidence for no effect for the rehabilitation of WRMSDs. CONCLUSIONS: Extrinsic feedback seems be a promising tool to improve sensorimotor control during work-related tasks in controlled environment (in prevention and in rehabilitation), that could positively influence the management of WRMSDs. These findings are clinically relevant for the use of extrinsic feedback in the clinic (a controlled environment) when simulating a work task. In addition, there are various technological but also non-technological source of extrinsic feedback (e.g. ergonomics counseling, strapping tape, mirror) that could be easily use by the clinicians to improve the sensorimotor control. As for the discrepancy of the results between the controlled and real environment, they could be explained by the fact that a specific task in controlled environment versus a task surrounded by unforeseen events in real world may not be similarly conducted. More evidence is needed concerning the effect of extrinsic feedback on sensorimotor control in the workplace.

P3-I-29 The modulation of corticospinal excitability and short-interval intracortical inhibition during the preparation of an individualized finger motor task.

Kaven Hamel[1], Alexandre Campeau-Lecours[1], Catherine Mercier[1], Véronique Flamand[1]
[1]Université Laval and Cirris

BACKGROUND AND AIM: Skilled use of the fingers is essential for daily life activities. However, fingers cannot act fully independently from one another, a phenomenon called finger enslaving (FE) that is more important between adjacent fingers. The preparation of selective finger movements involves control mechanisms within the primary motor cortex (M1). Prior to movement, corticospinal excitability is increased in the motor representation of the prime mover, whereas it is reduced in muscles controlling fingers that are not involved. This decrease in excitability is thought to result from an increase in short-interval intracortical inhibition (SICI), which would favor a better movement selection.

However, the relation between FE and the modulation of SICI during the preparation of a selective finger movement is still unknown. The aims of the project were 1) to describe the modulation of corticospinal excitability and SICI in the motor representation of the abductor digiti minimi muscle (ADM) during the preparation of individualized movements of the 2nd, 4th or 5th finger (ADM acting as a prime mover for the latter); and 2) to study the association between SICI of the motor representation of the ADM and FE measured during movements of the 2nd or 4th fingers. METHODS: A selective finger force production task with an instructed reaction time (RT) paradigm was performed using an apparatus comprising force sensors placed under the 2nd, 4th and 5th digits. Visual cues presented in random order indicated which of the 3 fingers to use to exert force on each trial. The measured forces were used to assess FE (force produced by a given finger when it is unselected / force when it is selected). Single and paired-pulse transcranial magnetic stimulation was used to measure corticospinal excitability and SICI at 3 time points before movement onset for each finger. Repeated measures ANOVA were used to assess the effect of TIME and selected FINGER. RESULTS: Nineteen healthy volunteers (9 females, 10 males; 38 ± 8.4 years old) were included. Consistent with previous studies, selection of the 5th finger was associated with a significantly greater FE for the 4th than for the 2nd finger. A significant interaction was found between TIME and FINGER on ADM corticospinal excitability. The amplitude of motor evoked potentials increased over time during motor preparation when the 5th finger was moving (i.e., when ADM was the prime mover) as well as when the 4th finger (i.e., adjacent finger) was moving, but not when the 2nd finger was moving. Analyses on SICI are ongoing and complete results will be presented at ISEK 2022. CONCLUSIONS: These first results suggest that the modulation of corticospinal excitability of the ADM muscle during motor preparation differs according to whether the 2nd or 4th fingers are instructed to move, even though ADM is not a prime mover for these fingers. This could be related to the greater level of FE observed between adjacent fingers.

P3-I-30 Precision stepping during a visuomotor gait task

Helle Hüche Larsen[1], Mikkel Damgaard Justiniano[2], Jens Bo Nielsen[1]
[1]University of Copenhagen, [2]Elsass Foundation

BACKGROUND AND AIM: Gait in a natural environment involves proactive visually guided modifications of the gait pattern. These modifications include adjustment of gait speed and ensuring precise foot placement when walking in uneven terrain. We aimed to investigate behavioral strategies when executing these common, yet complex, gait modifications. Therefore, we developed a methodology for investigating the effect of target on precision foot placement during gait. METHODS: Twelve neurologically intact adults (34 ±5.5 years, 6 females, 6 males) were enrolled in the study. Participants were asked to hit moving visual targets as precise as possible while walking on a treadmill. Targets and foot position were projected on a wall in front of the participant. We recorded kinematics, EMG activity from the lower extremities and gaze using eye tracking glasses in order to investigate behavioral strategy and error in foot placement in relation to target appearance, location, and speed. RESULTS: Preliminary results showed that precision error increased with speed. Targets located medially showed higher error than targets located laterally. Targets abbreviated compared to stride length showed the highest error, whereas neutral targets showed a minimum degree of error. Error also increased the further away- and the later a target was visually presented. Participants increased their step length and acceleration of forward swing when targets were presented. Furthermore, co-contraction was present during end of stance phase when opposite leg was attempting to aim for a target and also present in the leg aiming for the target. Gaze data indicates different strategies according to the complexity of the appearing targets. CONCLUSIONS: Neurologically intact adults use gait modifications such as elongation of base of support and co-contraction to increase precise foot placement when aiming for a target. Higher gait speed, shorter visual time span and targets requiring shortening or narrowing of steps in relation to target placement demonstrated higher precision error. The methodology will contribute to describing behavioral factors during a visuo-motor gait task, ultimately leading to development of a learning task mapping age-related visuomotor learning in individuals with and without brain lesion.

P3-I-32 Seeing our actual hand enhances the cortical processes related to sensorimotor adaptation when tracing with incongruent visual and proprioceptive feedbacks

Benjamin Mathieu[1], Antonin Abillama[1], Simon More[1], Catherine Mercier[2], Martin Simoneau[2], Laurence Mouchnino[1], Jean Blouin[3]

[1]Aix-Marseille University, [2]Université Laval, [3]CNRS

BACKGROUND AND AIM: Movement control is based on the integration of visual and somatosensory information. During a visuo-proprioceptive conflict, the movements become jerky and less accurate. However, studies have shown functional down-weighting of somatosensory information in contexts of visuo-proprioceptive conflict (e.g. hand seen in a mirror) that facilitates performance (e.g., Bernier et al. 2009). On the basis that post-effects after exposure to prismatic deviation are greater when subjects can see their actual hand than when they see a representation of its position (e.g., dot, Clower & Boussaoud 2000), we hypothesized that proprioceptive gating during sensory conflict requires subjects to see their hand. METHODS: We asked subjects to follow precisely the outline of a polygon with the tip of a hand-held stylus (Hand group: n=17) or with the tip of a 40 cm rod (Rod group: n=15). The Hand group could see both the hand and stylus. The Rod group could only see the distal portion of the rod and the digitizing stylus glued to it. Subjects performed 40 trials of 10 s in two conditions. Normal: the subjects saw the hand or rod directly. Mirror: the hand or rod was seen through a mirror. Performance was assessed by computing the number of zero crossings in the tracing velocity signal recorded by the digitizing tablet. Only the first 20 trials were analysed (i.e. trials showing the greatest errors in the Mirror condition). Brain activity was recorded by EEG (64 electrodes) and analyzed in the source space. We computed alpha (8-12 Hz) and beta (15-25 Hz) event related desynchronization (ERD)/synchronization (ERS) in the Mirror condition using the Normal condition as baseline. RESULTS: The ANOVA showed that tracing performance was greater in the Normal than in the Mirror conditions ($p<0.05$), but did not significantly differ between the Hand and Rod groups ($p>0.05$). For the Hand group, the somatosensory cortex showed a significant beta ERS in the Mirror condition suggesting a gating of somatosensory input. No significant ERS/ERD was found in this area for the Rod group. The Hand group also showed significant alpha and beta ERDs in the right (not left) posterior parietal cortex (PPC). These ERDs could be related to the role of the right PPC in processing visuospatial information (Krakauer et al. 2004). Again, no such ERDs were found for the Rod group. Finally, the visual cortex showed beta ERD in both groups, consistent with an increased processing of visual inputs in the Mirror condition. CONCLUSIONS: Overall, these results suggest that vision of the hand is necessary for re-weighing somatosensory information in contexts with incongruent visual and proprioceptive feedbacks. They also indicate that visuospatial computation in the PPC is facilitated by visual feedback of the hand. However, these cortical mechanisms, only observed in the Hand group, did not improve performance. Further analyses should determine if the amplitude of alpha and beta ERS/ERD are correlated with the tracing performance.

P3-I-33 Step height effects on double leg support time during stepping in place without vision

Nicole Paquet[1], Lucas Michaud[1], Yves Lajoie[1]
[1]University of Ottawa

BACKGROUND AND AIM: It is well known that stepping in place without vision is associated with unintentional body rotation [1]. In a previous study, we found that body rotation was larger when lifting the knees high compared with stepping at a comfortable step height [2]. We proposed that it was due to an increase in balance perturbation at high stepping, leading to incorrect repositioning of the feet on the floor from step to step. Possible imbalance at high stepping could be due to a shorter period of greater stability, which is the double leg support (DLS), compared to stepping at a comfortable step height. The aim of the study was to determine whether the DLS time is indeed shorter at high stepping during stepping in place without vision. METHODS: Fourteen participants (11 women, 22 ± 2 years) were blindfolded and stepped in place for 50 steps at a comfortable height and at high stepping (approx. 45° and 90 ° of hip flexion, respectively). Kinematic data from markers placed bilaterally on the heels, big toes and shoulders were recorded with the Vicon512TM system at 200 Hz. The DLS was defined as the period when the two feet were simultaneously on the floor, and it was identified from the vertical displacement of the heels and big toes. Body rotation was determined from the horizontal rotation of a line between the two shoulders. The dependent variables were the DLS time in second, the DLS in percent of the stepping cycle (DLS%) and body rotation in degree. The impact of step height on dependent variables was determined with paired t tests. RESULTS: The DLS time and DLS% were 0.15s (SD 0.03s) and 25.0% (SD 4.5%) at comfortable step height, and 0.13s (SD 0.03s) and 20.5% (SD 3.8%) at high stepping. Both were significantly shorter at high stepping (DLS time: $t(27) = 5.21$, $p < 0.01$; DLS%: $t(27) = 7.52$, $p < 0.01$). The body rotation was 26° (SD 20°) at comfortable step height and 35° (SD 29°) at high stepping, and was significantly larger at high stepping ($t(27) = -1.86$, $p < 0.05$). CONCLUSIONS: We found that the DLS time and DLS% were shorter at high stepping, and that it was associated with a larger body rotation than at a comfortable step height. It suggests that the reduced period of greater stability at high stepping could have led to a larger systematic foot angular error while repositioning the feet on the floor from step to step. Imbalance at high stepping could also be due to the greater perturbation of balance while in single leg support when the opposite leg was lifted higher and faster compared to stepping at a comfortable step height. Therefore, it appears that the decreased control of body rotation during stepping in place without vision at high stepping was likely due to a lesser stability and a greater balance perturbation. REFERENCES: [1] Nyabenda et al, Advances in Physiotherapy 6:122-9, 2004. [2] Grostern et al, Physiotherapy Canada 73:322-8, 2021.

P3-I-34 Bimanual coordination of filleting fish by the cutting movement of a kitchen knife in Japanese student

Takeshi SAto[1], Kimie Nakajima[2], Mizuki Nakajima[1], Kenichi Egawa[1], Eiji Watanabe[1], Miyu Kayama[3]
[1]Jissen Women's University, [2]Tokyo Kasei Gakuin University, [3]Junior College of Kiryu

People employed by enterprises have generally grown more advanced aged in recent years. The recent changes in the labor market was to continue to age. The fishing industry has formerly been perceived as particularly dangerous and physically fatiguing work due to the standing posture. The work is almost still characterized by frequent manual handling of cutting movement. Three pieces of wholesale of the fresh fish is one of the important motor skills for the Japanese cuisine, for example Sushi and Sashimi. Moreover, motor learning of filleting fish meat by the cutting movement of a kitchen knife were not easily and acquire as the motor tasks. In childhood, motor development is a basic process to ensure mastery in the face of daily and family motor activities. In the Japanese sushi chef, it was considered that the filleting fish work is to see and motor learning. There were no education of the filleting fish work in school age. The purpose of this study was to investigate for Japanese students to learn the filleting fish work themselves exercise of multiple times. It was compared between the chef's movement and student to analyze the acquisition of exercise as movement both hands. Two female students (age 20.30 ± 0.4 years, body height 153 ± 8.94 cm, body mass 48.57 ± 1.1 kg) were volunteers to participate in this experiment. Moreover, one professional cooker participated in this study as setmaster working process. All participants were right-handed and had no prior experience with the experimental task. The protocol was conducted in accordance with the Declaration of Helsinki (1975, revised 1983) and the local Ethics Committee approval (H2021-04). Subjects performed filleting fish meat a red sea bream by the cutting movement of a kitchen knife 4 times in a year. Surface EMG activity of the brachioradialis muscle and biceps brachii in both left and right arms was recorded while performing filleting fish using pre-gelled two 10-mm Ag-AgCl unipolar electrodes. The raw EMG activity was acquired with a sampling frequency of 500 Hz and accelerometer data with sampling frequency 100 Hz logger in Personal Computer. All statistical analyses were performed using SAS (university edition, USA) of one way repeated measures of ANOVA (= 0.05). Both hands at work of filleting fish were mainly three part work in process, de-scaled, removing entrails and fillet fish meat. It was decreasing the total operation time from 1100 seconds to 500 seconds as frequency four times operations. However, it was under seconds to operate by professional cooker. The EMG activity were not to decrease according to the working trials. It was tended to decrease the working time for cutting fish with the number of trials, however it was not to decrease about iEMG at brachial radial muscle. It was found that the working time for filleting fish by the cooking knife were shorter at the left and right upper arms with bimanual coordination. Although the results of motor learning to hold a knife in one hand were confirmed, the filleting fish motor skills of the Japanese cooks were extremely advanced.

J – Motor Disorders

P3-J-35 Increasing Excitability of the PPC Increases Gait Speed and Stride Length in Patients with Parkinson’s Disease with Freezing of Gait

Julien Clouette[1], Alexandra Potvin-Desrochers[1], Alejandra Martinez Moreno[1], Henri Lajeunesse[1], Freddie Seo[1], Gleydciane Alexandre Fernandez[1], Frédérike Parent-L'Écuyer[1], Audrey Parent[1], Alexander Fulford[1], Michelle Cheng[1], Caroline Paquette[1]
[1]*McGill University*

Background: Freezing of gait (FOG) commonly occurs in people living with Parkinson's disease (PD) and consists in brief and sudden episodes characterized by an inability to walk, despite the intention to do so. By increasing the risk of falling and reducing mobility, FOG imposes a burden on people with PD exhibiting this impairment. One brain region potentially responsible for the symptoms of FOG is the posterior parietal cortex (PPC), which is involved in visuospatial processing and sensorimotor integration. Neuroimaging studies have suggested a decreased activation of the PPC in patients with FOG, which may affect their ability to process and use the information provided by the environment, increasing the probability of a freezing episode occurring (Potvin-Desrochers & Paquette, 2021). Theta burst stimulation (TBS), a type of patterned repetitive transcranial magnetic stimulation (rTMS), could be used to excite the PPC and decrease the frequency and duration of FOG episodes. The goal of this study was to quantify the effect of excitatory TBS on FOG patients' gait characterized by very short strides and slow walking. Methods: Eight participants with FOG were included in this study. The study

consisted of three visits: an initial visit, and two experimental visits (excitatory intermittent TBS (iTBS) and sham, in a randomized order). Eight participants underwent the iTBS session, and six also completed the sham session. Participants performed a FOG-provoking walking task before and after stimulation of the PPC. The FOG-provoking test is a standardized task consisting of a sit-to-stand, walking, performing two 360-degree turns (in opposite directions), opening a door, walking through the doorframe, and walking back to the initial chair to sit down. This task was performed while holding a tray supporting a cup of water, as well as while counting down from 100 by intervals of 7. During the walking task, the participants were equipped with accelerometers in order to measure and record gait parameters and identify differences induced by the iTBS. Results: Preliminary analysis of the gait parameters showed no difference between the walking tasks before and after the sham stimulation in the 6 participants. On the other hand, iTBS yielded an increase of 12% +/- 14% in gait speed (P=0.048) and a 13% +/- 11% increase in stride length (P=0.013). These results seem to support visual evaluation of step number per turn and percentage of time spent frozen, which both had a tendency to decrease following iTBS (-5% +/- 13%, P=0.09 and -3% +/- 8% P=0.08, respectively). Conclusion: The increase in gait speed and stride length following an increase in excitability of the PPC suggest an improvement in walking mechanics. This could be caused by a better visuospatial processing or sensorimotor integration. Alternatively, the increased excitability of the PPC could indirectly increase the concentration of dopamine in the striatum, allowing the latter to better use sensory inputs. Potvin-Desrochers & Paquette, 2021, Neuroscience.

P3-J-36 Hand strength and force steadiness asymmetries in patients with Parkinson disease

Caleb Voskuil[1], Zoe Thijs[1], Adam King[1], Ryan Porter[1], Chris Watts[1], Joshua Carr[1]
[1]Texas Christian University

BACKGROUND & AIM: Muscle weakness and impairments in force control pose considerable challenges for people with Parkinson's disease (PwPD). Importantly, measurements of strength, force control, and muscle excitation have shown an asymmetric presentation of motor symptoms in PwPD. This experiment aimed to compare strength, submaximal force control, and muscle excitation between the dominant and non-dominant hands in a group of people with Parkinson's disease. METHODS: Six male participants with mild-moderate Parkinson's disease (Hoehn and Yahr scale: 1, n = 2; 3, n = 4) performed maximal handgrip contractions and submaximal index finger abduction tasks with both hands on two separate occasions following a familiarization session. Force tracing tasks required participants to match their index finger abduction force on a force template at 30% and 50% of their maximal voluntary contraction (MVC) force. The EMG root mean square (RMS) activity was detected from the first dorsal interosseous (FDI) muscle of both hands. The EMG activity during each submaximal contraction was normalized to maximal FDI EMG activity. Submaximal force steadiness was determined during the steadiest 3 seconds of the plateau phase of each force tracing as the coefficient of variation (CoV) of force. The testing order between hands and intensities was randomized and each variable was averaged across the two testing visits and retained for analysis. Paired samples t-tests were used to compare the mean values for maximal handgrip strength and index finger abduction force, submaximal force steadiness, and normalized submaximal EMG RMS values between the left and right hands. Alpha was set at 0.05 with Bonferroni adjustments to control for multiple comparisons and effect sizes for the mean comparisons were computed with Hedge's g. RESULTS: Mean comparisons for strength levels show a negligible effect for handgrip strength ($p = 0.509$, $g = 0.081$) and a small-moderate effect for index finger abduction MVC ($p = 0.027$, $g = 0.359$) favoring the dominant hand. Force steadiness comparisons demonstrate a moderate effect during the 30% MVC task ($p = 0.190$, $g = 0.653$) and a large effect during the 50% MVC task ($p = 0.009$, $g = 1.06$) with superior force control on the dominant side. The normalized EMG comparisons show small effects during the 30% MVC task ($p = 0.547$, $g = 0.298$) and negligible effects during the 50% MVC task ($p = 0.857$, $g = 0.091$) between hands. CONCLUSIONS: The present data show that a small cohort of PwPD exhibit considerable asymmetry of force control during index finger abduction. The effect size for the motor asymmetry was greater for the moderate (50% MVC task) versus the low (30% MVC task) intensity task, possibly reflecting greater impairment of higher threshold motor units. The greater asymmetry in force steadiness versus maximal strength suggests that assessments of force control may have greater sensitivity for the treatment and management of Parkinson's disease.

K – Motor Units

P3-K-37 Uncovering the neural drive of the human stretch reflex through motor unit activity and realistic simulations

Francesco Negro[1], Christopher Thompson[2]
[1]Università degli Studi di Brescia, [2]Temple University

BACKGROUND AND AIM: Over fifty years of research has contrasted the successive bursts of activity to muscle stretch. The earliest burst is termed the short-latency stretch reflex, occurs ~20-50ms following a sudden displacement, and is generated entirely by spinal circuits. The following burst is termed the long-latency stretch reflex, occurs 50-100ms following a sudden displacement and reflects supraspinal and spinal circuitry. To our knowledge, all previous studies of upper limb stretch reflexes contrasted the two epochs through peristimulus time histograms of net muscle activity or (very rarely) motor unit activity via indwelling electrodes. Peristimulus frequencygrams (PSFs) provide a complementary window to neural processing and require isolation of underlying action potentials of isolated motor units. And PSTHs and PSFs together provide a richer set of observations for computer simulations to reproduce and explain. Here we describe preliminary data using high-density surface EMG electrodes to non-invasively identify dozens of concurrently active motor units. METHODS: Six healthy individuals (23-47 yro) were seated with their right arm encased by a robotic exoskeleton while a high-density array electrodes was placed over their elbow flexor (brachioradialis) and elbow extensor (lateral triceps). Subjects performed a simple postural task: maintaining their hand within a 1 cm target against a constant flexion or extension torque at the elbow followed by a randomly timed pulse of elbow torque (100ms) which stretched or shortened the contracting muscle. Six blocks of 20 trials were collected. The resulting surface signal was decomposed into corresponding motor unit discharge times using an automated decomposition algorithm. Simulations were conducted with a two compartment, seven parameter Hodgkin-Huxley model. RESULTS: Muscle activity and motor unit discharge assessed with PSTHs showed the classic short-latency and long-latency bursts. PSFs, in contrast, revealed little change in motor unit firing frequency within the short-latency epoch and a large sustained increase within the long-latency epoch (~5X greater). Synaptic inputs that replicated the observed PSTHs and PSFs in the short-latency epoch were modelled as a succession of excitatory and inhibitory post-synaptic currents injected into the soma compartment of the motoneuron. In order to replicate the estimated excitation observed experimentally in the long-latency epoch, the simulated excitatory input had to overcome the motor neuron's afterhyperpolarization and were ~6x as large as those in the short-latency epoch. CONCLUSIONS: The clear differences in the neural drive for the two epochs are consistent with a major shift in neural control and demonstrate the utility of an extraction-simulation framework to explain stretch reflex activity.

P3-K-38 Mean Power Frequency of Boys and Men During Discrete, Progressive, Isometric Contractions Carried to Exhaustion

Jordan Langille[1], Stacey Woods[1], Raffy Dotan[1], Craig Tokuno[1], David Gabriel[1], Bareket Falk[1]
[1]*Brock University*

BACKGROUND AND AIM: Numerous physiological and performance-related child-adult differences have been observed, persisting even when body- and muscle-size differences are accounted for. One suggested explanation is that children do not utilize their higher-threshold (presumably, type-II) motor units (MU) to the same extent as adults. As type-I and type-II fibres differ in their conduction velocity and firing frequencies, the mean power frequency (MPF) of the electromyographic signal (EMG), may reflect differential MU recruitment. The purpose of this study is to examine potential MPF-pattern differences between children and adults during discrete, progressive, isometric knee-extensions. METHODS: Secondary analysis was performed on data of 17 boys and 20 men who completed a progressive isometric contraction protocol to exhaustion, consisting of 5-s isometric contractions, starting at 25% 1RM, and increasing by 3% every 5 contractions (Woods et al. 2019). EMG was recorded from the vastus lateralis. Independent t-tests were used to assess group differences in anthropometric variables, mean MPF (MPFmn), peak MPF (MPFPK), torque at MPFPK (%1RM), and MPF range. An interpolation polynomial was applied to each participant's mean stage MPF trend to account for the variance in the number of completed stages. Repeated measures ANOVA was then used to assess group differences in the various MPF patterns. In view of the boys' lower adiposity than the men's (10.1±7.5 vs. 17.1±5.6%), % body fat was used as a covariate. RESULTS: Boys reached a higher relative load at exhaustion compared with men (80.4±6.9 vs. 71.5±10.0 %1RM). MPFmn (109.7±17.6 vs 118.2±20.3 Hz) and MPFPK (113.8±17.9 vs. 124.1±22.0 Hz) were significantly higher in men. There was a significant group effect ($p<0.001$) in the MPF response, reflecting higher MPF in men throughout the protocol. MPF gradually increased and then decreased towards the end of exercise (stage effect, $p=0.006$), with large variability. The group-by-MPF interaction did not reach significance ($p=0.19$). 65% of the participants displayed the expected inverted-U MPF pattern. Within this subset, the torque at which MPFPK occurred was significantly higher in the boys compared with the men (60.4±20.6 vs. 46.7±10.7 %1RM). CONCLUSIONS: The boys' higher relative intensity at which MPFPK occurred, as well as their higher relative torque at exhaustion, suggest lower type-II muscle-fibre composition or lower type-II motor-unit activation in children. Overall, the results are in line with previous findings, suggesting lesser higher-threshold MU utilization in children. The underlying reasons for the variability in the observed MPF pattern and the potential confounding effects of contraction intensity and fatigue on child-adult differences, should be examined by future research.

P3-K-39 Local vibration decreases the contribution of persistent inward currents in voluntary contractions

Thomas Lapole[1], Ricardo Mesquita[2], Stéphane Baudry[3], Robin Souron[4], Callum Brownstein[1], Vianney Rozand[1]
[1]*Interuniversity Laboratory of Human Movement Biolgy,* [2]*Centre for Human Performance, School of Medical and Health Sciences, Edith Cowan University,* [3]*Laboratory of Applied Biology, Research Unit in Applied Neurophysiology,* [4]*UFR STAPS de Toulon, Unité de recherche IAPS (n°201723207F)*

INTRODUCTION: The motoneuron's response to synaptic inputs greatly depends on neuromodulation [1]. An important part of this neuromodulation is the activation of persistent inward currents (PICs), which amplify and prolong the effects of synaptic input [2], playing thereby an important role in

motoneuron discharge characteristics. PICs are known to be proportional to descending serotonergic and noradrenergic drive [2] which is thought to be enhanced as voluntary drive increases [3]. Accordingly, decreasing the voluntary drive during contractions performed to a given level of force should reduce PICs strength. To test this hypothesis, local vibration (LV), which induces excitatory drive from Ia afferents onto alpha motoneurons, was applied to the tibialis anterior muscle during voluntary ramp contractions. METHODS: High-density surface electromyograms (HD-EMG) of the tibialis anterior were recorded from a grid of 64 electrodes (GR08MM1305; OT Bioelettronica, Italy). Sixteen men performed 3 isometric triangular contractions of the dorsiflexors to 20 and 50% of maximal voluntary torque (MVC) without (CONTROL) and during 100-Hz LV of the tibialis anterior muscle. After HD-EMG decomposition and tracking of the same motor units (MUs) across conditions, we estimated PIC strength through a paired MU analysis [4], which quantifies MU recruitment-derecruitment hysteresis (ΔF; the greater the value, the greater the PIC strength). For each MU pair, the hysteresis of a higher-threshold MU (test unit) was quantified by calculating the difference between the instantaneous smoothed discharge rates of a lower-threshold MU (control unit) at recruitment and derecruitment of the test unit. RESULTS: After HD-EMG decomposition, we were able to identify 4.8 ± 3.7 test units and 28.8 ± 47.5 pairs per participant, and 9.1 ± 5.2 test units and 49.3 ± 64.7 pairs of MUs during 20 and 50% MVC ramps, respectively. LV induced a significant decrease in ΔF for both 20 and 50% MVC ramps ($p<0.001$). Estimated mean differences between CONTROL and VIB were -0.7 (95% CI: -0.5 to -1.0) and -0.5 Hz (-0.3 to -0.7) for 20 and 50% MVC ramps, respectively. CONCLUSION: These findings suggest that agonist LV decreases the contribution of PICs to tibialis anterior motoneuron firing during voluntary contractions. This effect is consistent with the importance of descending drive intensity in PICs strength in humans.
REFERENCES: 1. Heckman, C.J., et al. Clin Neurophysiol, 2009. 2. Heckmann, C.J., et al. P. Muscle Nerve, 2005. 3. Veasey, S.C., et al. J Neurosci, 1995 4. Gorassini, M., et al. J Neurophysiol, 2002.

P3-K-40 The effects of high-intensity without and low-intensity resistance training with blood flow restriction on the slopes of motor unit action potential amplitude versus recruitment threshold relationship

Tanner Reece[1], Mackenzie Bohn[1], Tera Hawes[1], Catherine Arnold[1], Gabrielle Dorsen[1], Bryan Vopat[1], Philip Gallagher[1], Trent Herda[1]
[1]*University of Kansas*

BACKGROUND AND AIM:Previous investigations demonstrate an increase in action potential amplitudes of higher-threshold motor units (MUs) following acute high-intensity (HI) resistance exercise training. Blood flow restriction (BFR) applied to low-intensity resistance exercise is believed to result in recruitment of higher-threshold MUs and does lead to increase in muscle fiber size. However, it is unclear if the action potential amplitudes following low-intensity resistance training with BFR would increase in a similar manner to that from HI resistance training. The purpose of the present study was to examine changes in the slopes of the MU action potential amplitude (MUAPAMP) vs. recruitment threshold (RT) relationship following HI resistance training and low-intensity resistance training with BFR. It is hypothesized that the slopes of these relationships will increase from HI training to a greater extent than low-intensity training with BFR due to the greater degree of type II fiber hypertrophy. METHODS: Eight males and 7 females were randomly assigned to perform either HI training (n=8, 4 females) or low-intensity training with BFR (n=7, 3 females). Leg-extension 1RM and maximal voluntary isometric contractions (MVCs) were performed for the leg extensors. Surface EMG signals of the vastus lateralis were collected during isometric contractions at 70% MVC with MUAPAMPS and RTs calculated

from the decomposed MU spike trains. MUAPAMP vs. RT relationships were calculated for higher-threshold MUs (RT >30%) and the slopes were analyzed. Training groups completed 3 sets of leg extensions to failure, 3x/week for 6 weeks. For HI, the load was set to ensure concentric failure was reached within the 8-12 repetition range, while BFR performed repetitions to failure using 30% 1RM with BFR applied to both legs. RESULTS: For 1RM strength, there was a statistically significant interaction (p=0.012). Both HI (Cohn's d [d]=1.47) and BFR (d =0.48) increased 1RM strength from pre- (HI:166.1±46.3 lbs, BFR:155.7±57.6 lbs) to post- training (244.4±65.3 lbs, 181.4±49.8 lbs) (p<0.001, p=0.003). There were no significant differences between groups pre- (p=0.694, d=0.20) or post-training (p=0.053, d =1.21). There was no significant interaction for MVIC strength (p=0.361) nor were there significant main effects for time (p=0.073) or group (p=0.290). For the MU data, 5 subjects were excluded per group due to insufficient MU yield or RT-range of higher-threshold MUs (>30% MVC). For the slopes, there was no significant interaction (p=0.324) nor were there significant main effects for time (p=0.364, d=0.38) or group (p=0.494, d=0.36). However, there was a moderate difference in magnitude (d=0.56) pre- to post-training for the slopes following HI training unlike for BFR training (d=0.13). CONCLUSIONS: These effect sizes align with previous reports that indicate greater type II fiber hypertrophy following HI training than low-intensity training with BFR.

P3-K-41 Earlier recruitment of motor units during isometric plantarflexion with restriction of blood flow is pronounced in the gastrocnemius muscles

Moeka Samoto[1], Jota Suzuki[1], Momoka Nakamura[1], Yasuhide Yoshitake[1]
[1]Shinshu University

AIM: Resistance exercise with low load combined with blood flow restriction (BFR) has been demonstrated to cause greater increase in muscle size and strength compared with that without BFR. The earlier recruitment of higher threshold motor units (MUs) by BFR has been suggested as a significant factor causing greater effect of resistance exercise with BFR on neuromuscular function, but there is few direct evidence for the alternations in recruitment threshold of motor units with BFR. Based on the characteristics of individual motor units with different enzymes and surrounding capillary density, the impact of BFR on MU recruitment threshold may be different between MU types, subsequently inducing the different MU activation strategies in the muscles with different muscle fiber type composition. Accordingly, the first purpose of this study was to test whether the recruitment threshold of MU can be lowered by BFR. This study also examined whether the lowering MU recruitment threshold by BFR depends on muscle fiber compositions. METHODS: Nine healthy adults performed isometric plantarflexion with 90° of ankle joint and fully knee extended positions. After the measurements of the maximal voluntary contraction (MVC) force, the participants were asked to increase their plantaflexion force linearly from 0 to 70% of the maximal voluntary contraction (MVC) with a rate of 10% MVC s-1. This task was repeated three times; before (PRE), 3-min after applying pressure at 200 mmHg to the tourniquet around the thigh (OCC), and 3-min after release of pressure (POST). High density surface EMGs were measured from the medial head of the gastrocnemius (MG) consisting of ~50% fast-twitch muscle fibers and soleus (SOL) with a predominance of slow-twitch muscle fibers during the tasks. Then MU discharge times were identified by the standard decomposition procedures with the convolutive blind source separation method. We employed MUs for further analysis that were able to identify in all three conditions. The recruitment threshold of each identified MU was expressed as % MVC, corresponding to the first motor unit spike. RESULTS: Because it was difficult for some participants to increase force linearly at around force onset, which induce less repeatability of MU recruitment threshold, we focused on MUs which recruitment threshold was above 10% MVC in PRE. With respect to MUs of MG (total 50 MUs), averaged MU recruitment threshold was smaller in OCC (17.0% MVC, P < 0.05) compared with PRE (22.1% MVC) and POST (19.9% MVC) while there was no difference between PRE and POST (P > 0.05). With respect to MUs of SOL (total 62 MUs), averaged MU recruitment threshold was not different (P > 0.05) between PRE (31.2% MVC), OCC (29.1% MVC), and POST (29.4% MVC). CONCLUSION: This study suggests that earlier recruitment of motor units is occurred in the medial head of the gastrocnemius not in soleus muscle during isometric plantarflexion with BFR.

L - Muscle Synergy

P3-L-42 Motor cortical responses during movement planning of reaching reflects excitation of flexor synergies

Thomas Augenstein[1], Chandramouli Krishnan[1]
[1]University of Michigan

BACKGROUND AND AIM Stroke survivors often exhibit loss of independent joint control due to the emergence of abnormal synergies. Previous research from our lab has used transcranial magnetic stimulation (TMS) to show that the neural substrates mediating these abnormal synergies are of cortical origin. However, examining abnormal synergies via TMS requires the ability to reliably elicit motor evoked potentials (MEPs) from multiple muscles, which may not be possible when the muscles are at rest in stroke population. This can be addressed with a small background muscle contraction to excite the motor pathways and to reduce motor threshold; however, abnormal movement coupling (e.g., elbow flexion with shoulder abduction) after stroke could confound the MEP analysis. This is because MEPs in the contracting muscles would be higher than non-contracting muscles; thus, if the participant contracted their elbow muscles while performing shoulder abduction, the MEPs in these muscles could be artificially coupled due to inadvertent co-contraction. Examining MEPs during movement preparation could address this issue because they will reflect the couplings formed in the motor cortex without the confound of muscle contraction. However, a general understanding of how MEPs are altered and coupled during movement planning in healthy adults is critical prior to studying in stroke survivors. Therefore, the objective of this study was to examine the coupling of motor evoked responses during movement planning of reaching in healthy adults. METHODS Eight participants volunteered for this study. During the experiment, participants sat in front of a table and reached for a target (a cup) placed in front of them from two different postures: "arm on lap" and "arm on table". After determining the average resting MEPs, movement onset was estimated by computing the time for biceps brachii EMG onset during a reaction time test. TMS was delivered to the contralateral motor cortex during the movement planning phase at five timing intervals: 200, 150, 100, 50, and 0 ms prior to movement onset. Ten trials were performed at each posture and timing interval, and the average was used in the analysis. Normalized peak-to-peak MEPs of anterior deltoid (AD), middle deltoid (MD), biceps brachii (BB), triceps brachii (TB), wrist extensors (WE), and wrist flexors (WF) were evaluated. For each timing interval, the MEPs between the resting and the corresponding reaching conditions were compared. RESULTS MEPs were generally higher during movement planning. When compared with resting MEPs, the MEPs of AD and WF were higher during 50 and 0 ms, MD were higher during 200, 50, and 0 ms, BB were higher during all intervals, and TB were higher during 100, 50, and 0 ms (all p's <0.05). CONCLUSIONS The observed increase in excitability of the elbow and wrist flexors during motor planning of reaching even in 'arm on table' position, where these muscles are not required to be activated, indicate that there is an inherent excitation of flexor synergies during reaching. Future studies should compare how motor cortical excitability is altered during the movement planning phase in stroke survivors.

P3-L-43 Motor control strategy of double leg circles in pommel horse

Kazuto Kamitaira[1], Shuhei Kameyama[2], kengo Wakui[1]
[1]Niigata university, [2]Niigata university of management / Niigata university

BACKGROUND AND AIM: Double leg circles can be performed on all parts of the pommel horse. However, depending on the position and orientation it can be difficult to perform in the same way. One reason for this is that the relative positions and heights of the obstacles to be avoided vary. Previous studies reported that the kinematic structures of side-circles and cross-circles are different because of the different distance between the supporting points, and that cross-circles have increased hip flexion and deviation from the correct orientation. However, how the differences in kinematic structures such as position and orientation affect motor control is not well understood. Studies using muscle synergy analysis show that synergy is consistent between different conditions in running and pedaling motions, and it is expected to be applied to double leg circles as same cyclic motion. Therefore, the purpose of this study is to clarify the motor control strategy of double leg circles under different conditions using muscle synergy analysis. METHODS: The subject performed 15 consecutive side-circles and cross-circles on a pommel horse used in regular competitions. The sEMG signals of the eight left and right dorsal muscles involved in rear support were recorded. The motion was captured by three high-speed cameras and a static coordinate system was defined with the center of the pommel horse as the origin. After that, the ankle joint midpoint displacement in the static coordinate system was calculated using the 3D DLT method and used to extract the analysis section. The ARV was calculated from the filtered signals, and 10 stable circles were extracted from the circles except for the first and last. These data were averaged and non-negative matrix factorization was performed to calculate the muscle synergy vectors and the synergy activity coefficients. We then classified muscle synergies between subjects by performing cluster analysis on the synergy vectors and compared muscle synergies between conditions. RESULTS: 3~4 muscle synergies were extracted from both types of circles. These were synergies activated before and after the front support, before and after the rear support. In particular, the right dorsal muscles contributed to the synergy activated before the rear support, and the left did after. CONCLUSIONS: The results show that the circles consist of synergies involved in front and rear support, with no differences depending on position or orientation. Thus, it was suggested that there is consistency in muscle synergies between conditions and no difference in motor control strategy in double leg circles of the pommel horse.

M - Neuromechanics

P3-M-44 The Cutaneous Rabbit Effect, interstimulus interval, and direction influence the subjective evaluation of quality and velocity of electrotactile sequences at the foot sole

Michael Apollinaro[1], Leah Bent[1]
[1]University of Guelph

BACKGROUND AND AIM: Postural reflex, balance, and control of gait are modulated by information from the cutaneous afferents on the foot sole. The tactile sense of stimulus quality and velocity (Vel) are of present interest due to their role in the kinesthetic evaluation of movement and the importance of varied tactile experiences in exteroception. The replication of tactile experiences with distinct natural qualities and velocities is of great interest for stimulating interfaces. When evoking tactile experiences

with spatiotemporal specificity, the impact of perceptual illusions must be noted. The Cutaneous Rabbit Effect (CRE) is a sensory illusion characterized by mislocalization of one or more events within a rapid sequence. The CRE has not yet been demonstrated in the glabrous skin of the foot sole. In this study, we evoke distinct subjective evaluations of electrotactile stimulus trains that differ in spatiotemporal parameters. The impacts of sequence direction, location, and the CRE on Vel and quality selection will be assessed. METHODS: 10 participants (5 women, 5 men, mean age: 25.6, SD: 3.4) evaluated three-1ms electrotactile pulses across threes site on the foot sole (1-proximal, 2-middle, 3-distal). Pulse sequences varied in interstimulus interval (ISI) (100, 160, 220ms) and stimulus train pattern (sites 1-2-3, 1-1-3, 3-2-1). Stimulus trains were selected to differ in direction and location [Heel-to-Toe (H-T), CRE, Toe-to-Heel (T-H)], respectively. The main outcome measures were visual analog ratings of Vel, selection of qualities from a word bank, and verbal indication of the train's direction and loci. RESULTS: A Generalized Estimating Equation (GEE) indicated main effects of ISI ($p<.001$) and train ($p<.01$) on Vel rating. Pairwise Vel ratings at each ISI differed significantly (ISI $p<.001$). Pairwise Vel ratings differed significantly between each Train (H-T vs CRE $p<.01$, T-H vs CRE $p<.01$, H-T vs T-H $p<.05$). Participants indicated that the CRE was present in 94% of CRE trials. GEEs indicated that stimulus parameters significantly influenced the selection of 5 qualities (Vibration, Buzz, Movement across skin, Shock, and Tickle). CONCLUSIONS: A main finding of the present work was that Vel and qualities were effectively evaluated and discriminated using a visual analog scale and word selection, respectively. Lower Vel ratings for T-H as compared to H-T stimulus trains indicates a perceptual bias in the speed evaluation between directions. The CRE trials were evaluated as faster than both directional trials despite being perceived at the same loci. The impact of stimulus parameters on perceptual quality indicates that even the slightly differed trains utilized in the present work significantly altered the experienced perception. Future work should aim to further differentiate stimulus parameters in order to reliably evoke distinct perceptual qualities and to further explore and utilize differences in directional and illusion experiences.

P3-M-45 Reflex latencies in shoulder muscles differ when recorded with surface and fine-wire EMG electrodes

Constantine Nicolozakes[1], Margaret Coats-Thomas[1], Daniel Ludvig[1], Amee Seitz[1], Eric Perreault[1]
[1]*Northwestern University*

BACKGROUND AND AIM: The analysis of reflexes in shoulder muscles with electromyography (EMG) can help inform how muscles respond to unexpected perturbations to the shoulder, potentially protecting from dislocation. Surface electrodes are a non-invasive option to record EMGs of superficial shoulder muscles, yet fine-wire electrodes are often required to record EMGs of deeper shoulder muscles. Comparison of shoulder reflexes between shoulder muscles, and specifically reflex latencies, often involves use of both electrode types concurrently. Unfortunately, differences in reflex characteristics that result from using different electrode types could bias comparisons of reflexes between muscles. Our aim was to determine how reflex latencies in shoulder muscles differ when EMGs are recorded with surface or fine-wire electrodes. METHODS: Data were collected from 7 healthy adults (3F/4M, 29±6 years old). Reflexes were elicited by a linear actuator which applied small, stochastic, anterior-posterior perturbations to translate the humeral head as subjects generated isometric torque at 5% or 10% MVC. EMGs were recorded from the anterior deltoid, posterior deltoid, and latissimus dorsi simultaneously with surface and fine-wire electrodes. We estimated reflex latency as the time after perturbation onset when the rectified EMG diverged from background by at least 2 standard deviations. Latencies were compared between surface and fine-wire recordings with linear mixed effects models. To account for

the potential confounding effects of filtering unique to the surface or fine-wire electrodes, we applied the same 100 Hz square wave signal directly to each electrode and measured the respective delays in peak response. RESULTS: Latencies computed from fine-wire recordings of reflexes were on average 6.6±1.6 ms (mean±CI) shorter than latencies computed from surface recordings ($P < 0.001$; Fig. 1). The differences in latencies between electrode type were most pronounced in the latissimus dorsi (average Δ: 8.0±3.2 ms shorter with fine-wire, $P < 0.001$). The differences were also relatively large in the anterior deltoid (average Δ: 7.3±2.7 ms shorter with fine-wire, $P < 0.001$) and posterior deltoid (average Δ: 4.5±2.2 ms shorter with fine-wire, $P < 0.001$). When applying the identical control signal to each electrode, only 1.4 ms of the shorter latencies in fine-wire electrodes could be attributed to electrode-specific differences in filtering. CONCLUSIONS: Reflex latencies were shorter when recorded with fine-wire electrodes than when recorded with surface electrodes. Differences in latency may be due to low-pass filter effects of subcutaneous fat, which would delay reflex onset in surface recordings only. Our results suggest that EMG recording with fine-wire electrodes is warranted when reflex timing is of interest.

P3-M-46 Determining the contributions of specific descending neural pathways in postural control

Cassandra Russell[1], Paul Stapley[1], Jonathan Shemmell[1], Nathan Difford[1], Alexander Stamenkovic[2], Caitlin Arpel[1]
[1]University of Wollongong, [2]Virginia Commonwealth University

Balance maintenance and postural control is achieved through coordinated activity in neural pathways descending from the cortex and brainstem to the spinal cord. However, the contributions of each pathway are not completely understood. It has been suggested that motor evoked potentials (MEP), propagated by descending motor pathways, can be divided into early and late sections of activity, reflective of the areas responsible for each. Transcranial magnetic stimulation (TMS) has potential to access subcortical pathways, and could potentially identify the specific activity from various descending pathways, when paired with conditions that preference the role of one pathway over another. Refinement of a technique that could give insight into the specifics of each tract's output could enlighten diagnoses of their integrity assist understanding and direct research to develop targeted therapies for clinical disorders. We present two studies aimed at assessing contributions of cortical and brainstem pathways to TMS responses during balance control: The initial experiment assessed the amplitude of a MEP in the gastrocnemius muscle, induced by TMS, with electromyography (EMG). Participants of varying ages were stimulated while seated, standing on both legs, and then standing on the left and right legs in turn. A second experiment was designed to investigate the impacts of environmental stability on the modulation of MEP responses. Similar techniques were utilised but instead of free standing, participants stood on a pendulum-like balance board and were required to maintain a neutral position. Centre of pressure (COP) and muscle activity were recorded for comparison with MEP components. All conditions had muscle activity controlled for and matched to eliminate the effect of increased recruitment. Experiment one saw a significant proportional decrease in the earlier portion of the MEP in the gastrocnemius muscle, resulting in a proportionally larger later portion when participants were in a position of higher postural demand. The later component was larger in the right leg during right single leg stance, and larger in the left leg during left leg stance. In experiment two, early portions of the MEP increased in the tibialis anterior, and late portions of the MEPs increased in the gastrocnemius muscle with instability, independent of tonic muscle activity. The latency and onset of the MEP was significantly affected by age. We conclude that early and late MEPs components are independently modulated in response to postural stabilisation requirements. These changes in components are indicative of different neural origins for the early and late MEP, which we suggest is the Corticospinal Tract (early MEP) and the Reticulospinal Tract (late MEP) due to their characteristics and roles in posture and balance. It was also concluded that age effects underlying neural control but balance measures like COP and muscle activity are not related to MEP changes. These findings represent initial steps in improving our understanding of the neural correlates of balance control in humans with non-invasive stimulation.

P3-M-47 Sex differences in trunk muscle activity using multichannel surface electromyography during pushing tasks

Jacqueline Toner[1], Usha Kuruganti[2]
[1]Dalhousie University, [2]University of New Brunswick

BACKGROUND AND AIM: Depending on the design of a pushing cart, a worker's overall capacity to push can vary by as much as 9.5%. Additionally, biological sex can have an influence as females typically have lower force and strength when compared to males. Given that overexertion is a common issue for workers in Canada, it is possible that female workers are at a higher risk of an injury solely due to their sex and the task involved. Thus, it is imperative to explore the physiological response when pushing heavy loads, and exploring if handle design influences the physiological demands. The aim of the current study was to examine the impact of handle design using multichannel electromyography (EMG), specifically handle height and orientation, on trunk muscle activity during pushing tasks between males and females. It was hypothesized that there would be a significant difference among trunk muscles muscle patterns and sex. METHODS: A total of twenty participants, male (n=10) and female (n=10) (mean age = 24.25 ± 4.28 years) completed 18 trials of pushing an industrial cart loaded with 475 lbs using six different handle combinations of handle height (hip (H) /shoulder (S)) and handle orientation (vertical (V) /horizontal (H) /semi-pronated (S)) over a five meter distance. The identification of handle combination is presented as the letter indicated above representing the handle height andorientation. Multichannel high density EMG (Sessantaquattro, OT Bioelettronica, Italy) data was recorded at 1024 Hz using semi-disposable 32-channel electrode grids placed over the left and right rectus abdominis, erector spinae and external obliques. Spatial distribution was estimated using the Root Mean Square (RMS) and 2-Dimensional (2D) maps to examine spatial features. A repeated measures ANOVA was used for statistical analysis with the alpha level set to 0.05. RESULTS: Female participants averaged significantly less (p=0.035) mean RMS values regardless of trunk muscles using the HH handle design compared to the SV handle design (Figure 1). Similarly, male participants demonstrated significantly less mean RMS values regardless of trunk muscles using the HH handle design compared to the SS (p=0.041) and HS (p=0.022) handle design. Furthermore, males demonstrated significantly less hand force when using the HH handle design than most handle designs ((HV: p<0.001); (SH: p<0.001); (SS: p<0.001); (SV: p<0.01)). Likewise, females pushing with the HH handle design resulted in significantly less hand force than almost all other handle designs ((HV: p<0.001); (SH: p<0.001); (SS: p<0.001); (SV: p<0.001)). CONCLUSION: Findings indicated the HH handle design required lower force output, while simultaneously requiring the least amount of muscle activation when initiating a push regardless of sex. Future research should compare other regions of the body involved in pushing (e.g. lower legs, shoulders) amongst sexes to further validate the HH handle design as optimizing one's performance regardless of potential predisposed biological strength limitations.

P3-N-48 **Effect of knee rehabilitation exercise with and without blood flow restriction on quadriceps femoris muscle size**

Christopher Cleary[1], Trent Herda[2], Ashley Herda[2]
[1]Univeristy of Kansas Edwards Campus, [2]Univeristy of Kansas

Low-load blood flow restricted (BFR) resistance exercise has been shown to result in acute increases in skeletal muscle size in healthy, active individuals. BFR is also becoming popular in rehabilitation settings to promote muscular responses following injury. However, the response from BFR to a common lower body post-surgical rehabilitation exercise has yet to be established. Therefore, the purpose of this project was to assess the changes of quadriceps muscle size prior to and after a unilateral knee rehabilitation exercise performed with and without BFR. Sixteen (9 M; 7 F; mean±SD: 21.4±2.9 years; 1.76±0.1 m; 79.7±9.9 kg) healthy individuals that have been resistance training at least 2x/week for 6-months volunteered to participate. Unilateral, isometric quad sets were performed with BFR (EXP) and without BFR (CON), with the order of conditions randomized. Participants completed four sets of the designated exercise (one set of 30 repetitions and 3 sets of 15 repetitions) with 30-seconds between each set and 10-minutes separating conditions. Rating of perceived exertion (RPE) was measured after each set on a CR-10 scale. Panoramic ultrasound was utilized prior to (PRE), immediately-post (IM), 30-min, and 60-min after each respective condition to assess muscle size of the rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM) on each leg. Images were analyzed offline for muscle cross-sectional area (mCSA), muscle thickness (MT), and echo intensity (EI). Separate 2x4 [condition (EXP, CON) x time (PRE, IM, 30-min, 60-min)] ANOVAs assessed statistical differences. Data were considered significant at P<0.05. There was a significant condition x time interaction for RPE (P<0.001). RPE was always greater in the EXP condition versus CON (all P<0.001). Post hoc tests indicated that there were no changes across time for RPE during CON (P=0.69). For RPE in EXP, set 3 (3.6±0.3 AU) and set 4 (3.8±0.3 AU) were both greater (P=0.001) than set 1 (2.7±0.2 AU) and set 2 (3.0+0.2 AU) with no other differences identified. There were no significant condition x time interactions in any of the selected muscles for mCSA (P=0.26-0.68), MT (P=0.41-0.89), or EI (P=0.20-0.42). There was a main effect of condition for VL mCSA (P=0.010), as EXP (30.94±6.9 cm^2) was greater than CON (29.11±6.6 cm^2) collapsed across time. There was also a main effect of condition for VM EI (P=0.007), as EXP (78.43±9.21 AU) was greater than CON (75.37±10.1 AU) collapsed across time. Lastly, there was a main effect of time for VL EI (P=0.024) but post-hoc analyses indicated no significant differences between timepoints. Although participants found the EXP exercise to be harder than CON, there were no acute changes for muscle size (mCSA or MT) across time in either condition. In conclusion, there appears to be no unique quadriceps femoris response to the addition of BFR to a common knee rehabilitation exercise.

P3-N-49 **Automatic analysis of ultrasound images for assessing lumber muscle thickness**

Xiaoli Zhang[1], Shane Coppenhaver[2], Kian Moslehi[1], Minoru Shinohara[3]
[1]Intelligent Fiber Optic Systems Corporation (IFOS), [2]Baylor University, [3]Georgia Institute of Technology

BACKGROUND AND AIM: Low back pain is a prevailing health problem among aging adults and people at a workplace with physically demanding activities, including the military. To understand the underlying mechanisms, anatomical and behavior characteristics of the trunk muscles have been assessed with ultrasound images. However, human vision's manual analysis has various limitations, including high inconsistency and uncertainty. Automatic analyses of ultrasound images have been developed to assess

the characteristics of the muscle-tendon complex of limb muscles, but not the trunk muscles. The purpose of the study was to develop an automatic analysis algorithm for lumber muscle thickness with ultrasound B-mode images and compare the results with the manual assessment. METHODS: The automatic thickness measurements were achieved in a hierarchical three-step analysis method. First, the resting and contraction statuses were automatically segmented from ultrasound videos using a principal component analysis method. Second, the extracted resting and contraction images were converted into black-and-white to find the top and bottom contours of L3 Spinous process. The critical slope of the bottom contour was used to find the land marker of the spine central joint region annotated by a bounding box. Lastly, the exact spine central point was filtered out by the pixel intensity value inside the bounding box. A threshold was put onto the bounding box to extract the regions whose pixel values were higher than 95% of the entire region. The centroid for the connected component with the highest average pixel value denotes the spine central joint, and it was used as the bottom endpoint for thickness measurements. A vertical line was then drawn from the bottom endpoint on the L3 Spinous process. The line intersection with the Lumbodorsal fascia denotes the top endpoint. Distance between these points was measured as the erector spinae muscle thickness. RESULTS: R2 was calculated between human and machine measurements for videos of 32 human adults. For resting conditions, R2 was 0.77, and for contraction conditions, R2 was 0.73. The high R2 values indicated a strong correlation between human and machine measurements. Under the resting conditions, the average difference in the mean value was 0.45 cm, which was 15% of the average human measured distance. The standard deviation for resting conditions was 0.3 cm. Under the contraction conditions, the average difference was 0.42 cm, which was 14% of the average human measured distance. The standard deviation for contraction conditions was 0.4 cm. For 182 images, the program took about 13.5 s to complete. The average detection speed for each image was about 0.07 s. CONCLUSIONS: Automatic analysis of ultrasound images of the erector spinae muscle via computer vision algorithms can objectively determine muscle thickness values comparable to manual analysis in a much shorter time. Supported by Department of Defense (W81XWH20C0049)

O - Pain

P3-O-50 Somatic pain distribution and its association with the clinical features in women with fibromyalgia.

Marco Barbero[1], Margarita Cigarán-Méndez[2], Edurne Úbeda-D?Ocasar[3], José Luis Arias-Buría[2], Gracia María Gallego-Sendarrubias[3], Juan Antonio Valera-Calero[3], César Fernández-de-las-Peñas[2]
[1]University of Applied Sciences and Arts of Southern Switzerland, [2]Universidad Rey Juan Carlos, [3]Universidad Camilo José Cela

BACKGROUND AND AIM: Fibromyalgia syndrome (FMS) is a disabling condition characterized by widespread pain and fatigue. Pain drawings (PD) are commonly used to obtain a topographical description of pain symptoms in people with chronic conditions. The knowledge derived from PD analysis may constitute an important aid for diagnosing and treating people with FMS. The aim of the present study is two-fold. First, to evaluate the somatic distribution of pain in people FMS using PDs. Second, to explore the association between pain extent (PE) and the clinical features of FMS patients. METHODS: One hundred twenty-six females diagnosed with FMS and no other co-morbid conditions were instructed to complete two paper pain drawings (dorsal and ventral views) by shading their usual pain symptoms. Pressure pain thresholds (PPT) were bilaterally assessed over a series of standard anatomical sites. Eventually, all participants completed two questionnaires to assess signs and

symptoms of central sensitization (CSI) and psychological factors (HADS). All paper body charts were scanned and imported into an online platform (https://syp.spslab.ch) that computed the PE and produced, by superimposing all the pain drawings, two topographic pain frequency maps. After conducting a multivariable correlation analysis to determine the associations between the clinical variables, a stepwise linear regression model was performed to identify PE predictors. RESULTS: Two topographic pain maps illustrating the most frequently somatic location of pain were obtained (Fig. 1). PE was positively associated with age (r = .183), years with pain (r = .267), mean pain intensity at rest (r = .247), pain during daily life activities (r = 0.269), CSI (r = .421), and anxiety levels (r = .300) (all, p < .001), and also negatively associated with PPT over the greater trochanter (r = -.224) and tibialis anterior (r = -.188) (both, P<0.05). The stepwise regression analysis revealed that 27.8% of the PE was explained by CSI, age, and years with pain symptoms. CONCLUSIONS: The pain frequency maps revealed a highly widespread somatic distribution of pain involving commonly (>50%) joints and with the highest frequency (>80%) for the neck and shoulders region. Moreover, PE was moderately associated with signs and symptoms of central sensitization in women with FMS. Higher PPT over the greater trochanter/tibialis anterior, older age and longer pain history were very weakly associated with larger PE.

P3-O-51 Effect of Physical Therapy protocol on pain, function, posterior capsule tightness and range of motion in individuals with posterior capsule tightness and rotator cuff related shoulder pain ? A Prospective Cohort Study

Dayana Rosa[1], John Borstad[2], Júlia Ferreira[3], Vander Gava[3], Paula Camargo[3]
[1]Université Laval, [2]The College of St. Scholastica, [3]Universidade Federal de São Carlos

BACKGROUND AND AIM: Posterior capsule tightness (PCT) is a prevalent tissue adaptation in individuals who perform overhead activities and has been associated with rotator cuff related shoulder pain (RCRSP). Shoulder internal and external rotation range of motion (ROM) alterations have been also described in those with PCT, with or without shoulder pain, with poorer function reported in individuals with combined conditions [1]. Since PCT and RCRSP are often related to shoulder ROM alterations and functional limitations, studies evaluating the effectiveness of treatment for pain and PCT overtime may help clinicians make treatment decisions. The purpose of this study was to evaluate the effects of a specific physical therapy intervention targeting RCRSP and PCT on shoulder pain and function, PCT and internal and external ROM in individuals with both conditions present. METHODS: Thirty-one individuals with RCRSP and PCT were included in this study (41.06±12.8yrs; 76.9±13.72kg; 1.71±0.09m; 41.9±53.97 months of pain). RCRSP was confirmed by a clinical examination and self-reported history. PCT was determined by quantifying a difference between shoulders of at least 7° in the low flexion (LF) test [2]. Pain and function were evaluated by Shoulder Pain and Disability Index (SPADI) questionnaire. Internal and external rotation ROM was measured with a digital inclinometer at 90° of shoulder abduction with 90° elbow flexion. All variables were evaluated at pre- and post-treatment (follow-up 1); 4 weeks (follow-up 2) and 8 weeks (follow-up 3) after treatment period. The protocol was performed 3 times per week for 4 weeks and included posterior capsule mobilization (5min), sleeper stretching (3x30s) and external rotator strengthening (3x10rep). A One-way ANOVA was used to compare variables over time with significance set at p<0.05. RESULTS: After treatment, decreased SPADI scores were found when baseline was compared with follow-ups 1, 2 and 3 (P<.01; Mean Difference [MD]= 28.18; 32.46; and 35.30, respectively); and when follow-up 2 was compared to follow-up 3 (P=.01; MD=7.08). Individuals also showed increased motion on the LF test at follow-ups 2 and 3 when compared to baseline (P=.001;

MD=-6.04 and -7.19, respectively). Increased internal rotation ROM was demonstrated only when baseline was compared to follow-up 3 (P<.001; MD=10.49) and between follow-up 1 and follow-up 3 (P=.03; MD=-7.93). No external rotation ROM differences were identified (P>.05). CONCLUSIONS: The present study was the first to assess the effect of a physical therapy intervention specifically targeting shoulder pain and PCT. Although a control group was not included in the present study, the results revealed that the targeted treatment approach improved pain and function, decreased PCT, and increased shoulder internal rotation ROM immediately and at 4 and 8 weeks after treatment concluded. The sustained improvement over time suggests that an intervention targeting PCT in individuals with both PCT and RCRSP should be considered in clinical practice. REFERENCES: 1) Rosa et al. Phys Ther. 2019;99:870-88; 2) Borstad JD & Dashottar A. J Orthop Sports Phys Ther. 2011;41:90-99.

P - Rehabilitation

P3-P-53 The effect of Thermal Therapy and Exercises in Acute Low Back Pain: a protocol for a Randomized Controlled Trial

Claudia Côté-Picard[1], Jean Tittley[1], Catherine Mailloux[2], Kadija Perreault[3], Catherine Mercier[3], Clermont E. Dionne[4], Jean-Sébastien Roy[3], Hugo Massé-Alarie[3]

[1]Centre interdisciplinaire de recherche en réadaptation et intégration sociale, [2]Clinique Physio-Interactive Cortex, [3]Centre interdisciplinaire de recherche en réadaptation et intégration sociale - Université Laval, [4]Centre de Recherche du CHU de Québec - Université Laval

BACKGROUND AND AIM: Low back pain is the 1st cause of disability worldwide, due to the development of chronic pain. Thus, it is necessary to identify the best treatments in acute low back pain (ALBP) to limit the transition to chronic low back pain (CLBP). Guidelines recommend to use non-pharmacological treatments in ALBP. Thermal therapy (TT) presents the strongest evidence (moderate) for short-term reduction in pain and disability, but its long-term effect remains unknown. One randomized controlled trial (RCT) showed that the addition of TT to exercise provides greater short-term improvement in disability than exercise or TT alone. TT could potentiate exercise effect in ALBP and prevent transition to CLBP. Also, many mechanisms underlying TT benefits have been hypothesized, but few have been tested. Muscle relaxation at the site of TT could be partially responsible for pain relief because ES hyperactivation is present in some CLBP patients. Objectives: (i) to determine the short/long-term effects of TT ± exercises on disability and pain, (ii) to verify the immediate/short-term effect of TT on erector spinae (ES) activity and (iii) to determine if ES activity is related to intervention effects. METHODS: In this RCT, 99 adults with ALBP will be recruited. At baseline, disability, pain and ES activity will be measured and participants will be randomly assigned to 1 of 3 groups: 1) TT, 2) TT + exercises and 3) control. Participants in groups 1) and 2) will wear a heatwrap over the lumbar spine for 1 hour, and those in group 2) will also perform an exercise program. After one hour, ES activity and pain will be measured again. Interventions will be done at home for 7 days. Participants in groups 1) and 2) will wear a heatwrap for 8 hours x 7 days and those in group 2) will also perform an exercise program (30 min/day x 5 days/7). Participants in group 3) will wear a room temperature heatwrap to control for the proprioceptive and support effects of the heatwrap. The primary outcome is disability (Oswestry disability index-ODI) and secondary outcomes are pain intensity (numerical rating scale-NRS), and ES activity (EMG at T12 and L5). Pain and disability will be measured at baseline and at 1, 4, 12 and 24 weeks. ES activity will be measured at baseline, after 1 hour (pre/post-1st treatment) and after 7 days of treatment. STATISTICAL ANALYSIS: All outcomes will be compared between groups with a generalized linear mixed model incorporating terms for Group and Time, and Group x Time interaction with random

effect for participants. For objective (iii), a multiple linear regression will be computed to determine if baseline ES EMG is related to change in pain and disability. SIGNIFICANCE: This study will provide new evidence on the effect of non-pharmacological interventions (TT ± exercises) on ALBP and will allow to determine if the assessment and treatment of ES activity through TT ± exercises may help to improve the management of this burdensome condition.

Q – Robotic Rehabilitation

P3-Q-56 Powered Lower-limb Exoskeleton for Human Gait Analysis Dataset

Renato Baptista[1], Svonko Galasso[2], Serena Pizzocaro[3], Francesco Salvaggio[4], Micaela Schmid[5], Alessandro De Nunzio[1]
[1]LUNEX International University of Health, Exercise & Sports, [2]Department of Electrical and Information Engineering, University of Cassino and Southern Lazio, [3]Department of Electrical, Computer and Biomedical Engineering, University of Pavia, [4]Department of Public Health, Experimental and Forensic Medicine, Department of Sport Science, Univer, [5]University of Pavia

BACKGROUND AND AIM: Powered lower-limb exoskeletons are a new and emerging technology representing a promising solution for rehabilitating gait in various situations such as regaining locomotion ability and addressing gait impairments. This technology has been studied and adopted in gait rehabilitation due to the increasing number of patients with gait impairments caused by spinal cord injury (SCI), stroke, injury, or other related pathology. Furthermore, lower-limb exoskeletons can provide effective gait training and improve human performance in walking situations. To ensure that such devices meet the needs of the users and enhance human walking-like tasks, it is necessary to investigate and understand the human-exoskeleton interaction. Therefore, the purpose of this study is to collect and analyse human gait information obtained from electromyography sensors (EMG) and inertial measurement units (IMU) while wearing a powered lower-limb exoskeleton. METHODS: In order to investigate this further, this study aims at collecting data from two different walking conditions wearing an exoskeleton ExoAtlet II (ExoAtlet Global SA, Luxembourg): walking overground and walking on a treadmill at a natural speed. The study was supported by the European Project H2020-779963 EUROBENCH STP-2. Dataset consisted of 30 healthy participants (15 male and 15 female, 23 years old ± standard deviation of 2 years) performing the two walking conditions. A set of wearable sensors, composed of 9 IMUs, attached on the human body (foot, shank, thigh placed on the left and right side, pelvic, lower and upper thoracic), and 4 surface EMG sensors, placed on 4 dominant leg muscles (tibialis anterior, soleus, vastus lateralis, and biceps femoris) was used for acquiring data. RESULTS: The results obtained by the data analysis give important information about the gait with the exoskeleton like the gait event detection (heel strike and toe off), which then can be used to segment gait cycles and perform analysis on the motion and muscle level. These evidences can be used to perform healthcare-related studies, exoskeleton simulations, and exoskeleton gait modelling to predict future gait events. CONCLUSIONS: Preliminary conclusions on gait event detection using a reduced number of inertial sensors show promising results. Furthermore, for future work, these results can be used as input for machine learning or deep learning algorithms towards a human gait predictive model.

P3-Q-57 Intuitive prosthesis control based on residual (stump) motion tested with valid subjects and amputees on the robotic platform REACHY

Bianca Lento[1], Océane Dubois[2], Effie Segas[1], Vincent Leconte[1], Pierre Rouanet[3], Matthieu Lapeyre[3], Rémi Klotz[4], Daniel Cattaert[1], Aymar de Rugy[1]

[1]Univ. Bordeaux, CNRS, EPHE, INCIA, UMR 5287, [2]CNRS, UMR 7222, ISIR / INSERM, U1150 Agathe-ISIR, Sorbonne Université, [3]Pollen Robotics, [4]CMPR Tour de Gassies

BACKGROUND AND AIM: We showed on a companion study that an Artificial Neural Network (ANN), trained to reconstruct distal joints from proximal (shoulder) motion plus information about movement goals, enabled a group of 7 transhumeral amputees to pick-and-place bottles as well as with their natural arm, in a Virtual Environment. Here, we aim to extend this proof of concept to the real physical world, by applying and testing a similar control scheme to reach and grasp real objects with the dedicated robotic platform REACHY. METHODS: Two control types were designed to enable subjects to reach and grasp objects using the robotic platform REACHY, a 3D-printed human like robotic arm used as a testbed for human-robot control strategies. The first one, Natural Arm control, uses ongoing arm movements of the operator to reproduce in real-time the same arm configurations on REACHY. The second one, Intuitive Prosthesis control, uses predictions from an ANN previously trained on natural arm movements to operate distal joints configuration (elbow, forearm, wrist). In Exp1, 12 subjects with valid arms were required to reach and grasp sponges of various positions and orientations in the frontal plane in front of REACHY with the two control types. Three blocks of 5 sponges (15 trials total) were conducted with each type of control, with alternating control type between blocks, and with an order counterbalanced between subjects. In Exp2, 2 participants with an amputation at humeral level, and 1 with a congenital limb deficiency, performed the same task with the Intuitive Prosthesis control. RESULTS: Participants of Exp1 were able to reach most objects with both types of control (medians of successful reach and grasp actions of 15 and 14, out of a total of 15 trials, for Natural Arm control and Intuitive Prosthesis control, respectively), and with similar movement times (median 6.05s and 6.35s for Natural Arm and Intuitive Prosthesis controls, respectively). Similar performances were obtained from the two transhumeral amputees and the individual with congenital limb deficiency in Exp2. CONCLUSIONS: Our Intuitive Prosthesis control, based on predictions of distal joints from proximal (shoulder or stump) motion and knowledge about movement goals, enables to reach and grasp real objects with REACHY as well as with a control based on real arm movements. However, movement times recorded here (about 6s) remained much higher than typical movement times obtained with natural arm movement (similar task in virtual environment elicited movement times of the order of 1s), and the workspace on which we tested this control was much reduced. Ongoing work explores mechatronic issues as well as the use of compensatory movements from the trunk and the shoulder complex (not included at present) to improve these control strategies.

R - Sports Science and Motor Performance

P3-R-58 Application of muscle synergy in skills assessment of gymnastics

Shuhei Kameyama[1], Yukihiko Ushiyama[2], Takehito Mori[3], Yuki Sato[2], Kengo Wakui[2], Kazuto Kamitaira[3]
[1]Niigata university of management / Niigata university, [2]Niigata university, [3]Niigata university of management

BACKGROUND AND AIM: In this study, we applied muscle synergy as a skills assessment by surface electromyography (EMG) in gymnastics. Muscle synergy is suggested as a motor control strategy of the central nervous system, that can be extracted by non-negative matrix factorization (NMF). Gymnastics requires more specialized and technical movements (e.g. rotation and handstand) compared to other sports. These movements don't depend only the muscular endurance and power of individual muscles, that can be achieved through muscle coordination. However, few studies to evaluated muscle synergy in gymnastics. In addition, "ideal control of the body" is very important to improve performance, and

clarification of muscle coordination (i.e. skillful movement) is required. In this study, we extracted the muscle synergy of the back handspring, and applicability as a skills assessment in gymnastics. METHODS: Five male university gymnasts and five male university students who had been acquiring the back handspring for less than one year were selected as participants. Ten muscles were selected from the whole-body (triceps brachii: TB, biceps brachii: BB, anterior deltoid: AD, posterior deltoid: PD, rectus abdominis: RA, erector spinae (longissimus): ES, rectus femoris: RF, biceps femoris: BF, tibialis anterior: TA, gastrocnemius: GA). Movement phase of the back handspring was divided into five time points (rest, pre-jump, take-off, handstand, and landing). Muscle synergies were extracted by non-negative matrix factorization (NMF) based on each EMG after noise processing, rectification, and smoothing with a low-pass filter (10 Hz). RESULTS: Five muscle synergies were extracted from the activity patterns of 10 whole body muscles. Three of these muscle synergies were commonly extracted among the participants. The time series components (activation coefficient) showed that #1: arm swing, #2: jumping and landing, #3: handstand to landing. Muscle weightings showed that #1: upper limb (mainly shoulder extension) with high values of BB and AD, #2: lower limb (jumping and landing) with RF and TA, and #3: upper limb (mainly handstand) with TB, AD, and PD. In addition, ES contributed to pre-jump to handstand phase. RA contributed to handstand to landing phase. CONCLUSIONS: In this study, we are planning to compare muscle synergy in gymnastics by skill level to applicability as a skills assessment. However, progress has been delayed due to the COVID-19. Therefore, the conclusion on the applicability of muscle synergy will be presenting at the conference. At this stage, the extracted synergies show the main movements in back handspring. This showed that the details of each subject's motor control strategy can be explained by the muscle synergy.

P3-R-59 Altered gastrocnemius activation in individuals with Achilles tendinopathy revealed using high density electromyography in dynamic functional tasks

Smita Rao[1], Vaibhavi Rathod[1], Seyed Yahya Shirazi[1], Rory O'Keeffe[1], S. Farokh Atashzar[1]
[1]NYU

BACKGROUND AND AIM: Achilles tendinopathy (AT) is a highly prevalent overuse injury. Altered gastrocnemius activation has been postulated to lead to increased tendon loads and ultimately, tendon degeneration in AT. However objective evidence is conflicting, partly due to the limitations of conventional bipolar electromyography (EMG). The purpose of this case-control pilot study is to compare gastrocnemius activation during dynamic tasks in individuals with and without AT using high density (HD) EMG. METHODS: All procedures were approved by our institutional review board. Two individuals with AT (27/M, 39/F) were compared to asymptomatic controls (32/M, 45/F). Individuals with AT reported tendon pain 2-6 cm proximal to AT insertion) for at least 3 months while running, jumping, or hopping. Surface HD EMG data were collected using two 13 x 5 cm grids of 64 electrodes (Quattrocento, OT Bioelectronica SRL, Italy) placed on the gastrocnemius medialis and lateralis using placement guidelines from the Atlas of Muscle Innervation Zones. After skin preparation, adhesive foam electrodes filled with electro-conductive paste were secured, and reinforced with a surgical dressing. A reference electrode was placed at the ankle. HD EMG signals were recorded in monopolar mode at 2048 Hz during a single leg heel raise and a repeated hopping task. HD EMG were band-pass filtered (3-200 Hz), Root Mean Square (RMS) amplitude was calculated for each bipolar derivation. Barycenter and mean differential activation per grid was calculated. Descriptive statistics and between-group effect sizes (Cohen's d) are presented for barycenter and mean differential RMS. RESULTS: Mean barycenter (right) and mean differential RMS (left) are depicted in Figure 1. Grey columns indicate AT, white columns indicate control participants, HR: Heel Raise, HOP: Repeated Hopping, Med: Medial Gastrocnemius, Lat: Lateral Gastrocnemius. Individuals with AT demonstrated more distal barycenter in the gastrocnemius during the heel raise (Effect size 0.89 and 2.10, medial and lateral gastrocnemius, respectively) and repeated hopping tasks (Effect size 2.5 and 0.55, medial and lateral gastrocnemius, respectively) Higher mean differential RMS was noted in the heel raise (Effect size 0.69 and 0.88, medial and lateral gastrocnemius, respectively). Higher mean differential RMS was noted in the lateral but not medial gastrocnemius during repeated hopping (Effect size -1.30 and 0.97, medial and lateral gastrocnemius, respectively). CONCLUSION: Our pilot study found notable differences in gastrocnemius muscle activation during two dynamic tasks in individuals with AT compared to asymptomatic controls, in particular more distal barycenter and more heterogeneous activation in individuals with AT. Studies are underway to increase the sample size, and examine whether altered gastrocnemius activation may contribute to tendon degeneration and symptom severity in AT.

P3-R-60 Low Back Pain in Student Circus Artists: An exploratory study and comparison between the Oswestry Disability Index and the Athlete Disability Questionnaire

Bianca Rossini[1], Meagan Anstruther[1], Maryse Fortin[2]
[1]Concordia University, [2]Concordia

Background and Aims: Low back pain (LBP) is a major global health issue. Athletes and performing artists also suffer from LBP. Student circus artists' unique daily training (minimum of 25 hours/week) put constant stress on their spines and back. Proper back muscle function is critical for spinal stability and movement. While the literature on circus artists is scarce, the ankle and spine were reported as the most injured anatomical locations and prime targets for prevention interventions. However, the presence and severity of LBP in this unique athletic population remains unclear. Therefore, the purpose of this study was to 1) To explore the prevalence and severity of LBP in current student circus artists in Quebec, and 2) to compare scores between the Oswestry Disability Index (ODI) and the Athlete Disability Index (ADI) questionnaire to assess the level of disability in circus artists reporting LBP. Methods: Thirty-three students (19 females and 14 males) aged 18-29 years (mean age: 21.15 0.435) in the college circus program from the National Circus School in Montreal and the Quebec Circus Arts School in Quebec City were recruited. Participants filled out a self-reported questionnaire on demographics, training history, and LBP history in the past year. Participants who reported LBP also filled a numerical pain rating scale (NPRS; scale 0-10), ODI (max score of 50) and ADI (max score of 36) to measure LBP disability. The ODI and ADI scores were converted to a % and the level of LBP disability was classified as mild, moderate, or severe as previously defined by each scale. Descriptive statistics were obtained for the population and LBP characteristics. Pearson's correlation coefficients were calculated to evaluate the relationship between the NPRS (converted to scale 0-100), ODI and ADI scores. Results: A total of 18 students (54.55%) reported LBP; 12 were classified as chronic LBP (pain lasting over 3 months) and 6 as acute LBP (pain lasting less than 4 weeks). The pain intensity mean on NPRS was 4.528 0.435. The mean score for ODI and ADI was 9.333% 1.808 and 16.203% 2.678, respectively. Pearson's correlation coefficient between ODI and ADI was 0.769 [95% CI: 0.526, 0.917] ($p<0.001$), 0.288 [95% CI: -0.268, 0.746] ($p=0.247$) between the NPRS and ODI, and 0.523 [95% CI: 0.005, 0.842] ($p=0.026$) between NPRS and ADI. Based on the ODI scores, 88.89% of the artists reporting LBP were classified has having mild disability, 11.11% moderate disability, and 0% severe disability as compared to 66.67%, 27.78% and 5.55% with the ADI, respectively. Conclusion: Our findings provide novel insights regarding high prevalence of LBP in circus artists and warrants further examination. While the correlation between ODI

and ADI was strong, our findings suggest that the ADI may be a better tool to assess LBP-related disability in athletes due to more accurate classification of the levels of disability and statistically significant correlation with the NPRS.

P3-R-61 Cutaneous stimulation of the foot sole does not alter rate of torque development during maximal effort, plantarflexion contractions

Tushar Sharma[1], Giacomo Passarelli[1], Davis Forman[1], Avery Hinks[1], Vincenzo Contento[1], Geoffrey Power[1], Leah Bent[1]

[1]*University of Guelph*

BACKGROUND AND AIM: The ability to generate torque quickly, particularly in the leg muscles, is important to generate postural responses to perturbations to prevent loss of balance. In certain populations that exhibit postural deficits (e.g. older adults), there is a slowing of rate of torque development (RTD), partially due to a slowing of intrinsic contractile properties. In the hand, it has been shown that electrical stimulation of cutaneous afferents changes motor unit threshold such that higher threshold motor units which consist of fast muscle fibres are recruited earlier during a contraction. Therefore, electrical stimulation of cutaneous afferents during voluntary contractions may increase RTD, by recruiting high-threshold motor units earlier. To date however, whether cutaneous stimulation of the foot sole alters RTD remains unknown. Therefore, we aimed to determine the effects of electrical cutaneous stimulation on RTD. METHODS: Ten healthy, young females (mean age ± SD: 24.1 ± 3.9 years) were seated on a Humac Norm Dynamometer (ankle: 90°, knee: 110°, hip: 80°) and performed maximal effort plantarflexion contractions as quickly and forcefully as possible. Contractions were performed during a non-nociceptive electrical stimulation (1 ms pulses delivered at 300 Hz) of the plantar heel (STIM) and no stimulation control condition (NO STIM). Participants performed 4 blocks of 5 contractions (20 contractions) per condition. For each contraction, we measured RTD by calculating the slope in 0.025s time epochs up to peak torque (i.e. 0-0.025s, 0.025-0.050s, 0.050-0.075s etc.). In addition, we calculated RTD after normalizing torque to peak torque during a maximal voluntary contraction. Normalized and absolute RTD were compared in each time window between STIM and NO STIM conditions. RESULTS: RTD did not significantly differ between STIM and NO STIM for both absolute (NO STIM: 24.2 ± 7.5 Nm/s, STIM: 24.4 ± 7.5 Nm/s; p = 0.69) and normalized calculations (NO STIM: 32.5 ± 9.5 %MVC/s, STIM: 32.5 ± 9.3 %MVC/s; p = 0.98). CONCLUSIONS: These results indicate that in a healthy, young female population cutaneous stimulation of the foot sole may not increase RTD during brief bouts of rapid isometric plantarflexion contractions. Our findings may suggest that cutaneous input from the foot sole did not alter excitability of motor neurons in a way that altered their recruitment threshold or firing rate in our participants, although we did not measure motor unit recruitment or rate coding. Given there was no difference in RTD for the STIM and NO STIM conditions, cutaneous stimulation of the foot sole may not be an effective tool to improve RTD in plantar flexor muscles in a young healthy population.

THANK YOU TO THE SPONSORS, EXHIBITORS AND SUPPORTERS FOR THEIR SUPPORT OF ISEK

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