MODULATING EFFECT OF DIFFERENT UNLOADINGS ON THE LOWER LIMB NOCICEPTIVE WITHDRAWAL REFLEX RECEPTIVE FIELDS

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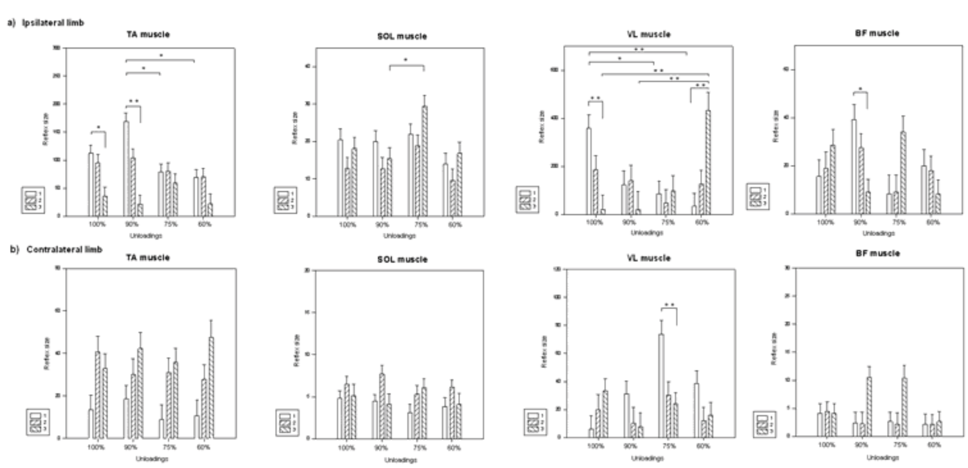
AIM: The purpose of this study was to investigate the effects of unloading the body on the multi-joint nociceptive withdrawal reflex (NWR) receptive fields organization during symmetrical upright standing in humans.
METHODS: Fourteen healthy volunteers participated in this study. Two platforms were used to acquire ground reaction forces. EMG activity was recorded through a pair of Ag/AgCl surface electrodes placed bilaterally over vastus lateralis (VL), biceps femoris (BF), tibialis anterior (TA), soleus (S). The NWR was elicited by cutaneous electric stimulation (20 msec trains of five pulses given at 200 Hz) delivered on the sole of the foot in three different locations: mid-forefoot, arch of the foot and heel. Each subject stood upright with the feet parallel on the force plates. A visual feedback allowed participants to load equal weight on each foot. Participants worn a whole-body harness connected via a rope to a pulley. Securing the rope to an overhead bar allowed unloading of varying degrees. Patients were recorded at 100, 90, 75 and 60% of their body weight. Five to seven trials, for each stimulus site, were recorded in each subject. The order of the sites of stimulation and unloading conditions were randomized. We measured the root mean square (RMS) in pre- and post-stimulus equivalent time windows. To detect the reflex activity we measured a reflex threshold in the pre-stimulus trials (fixed at mean+ 2SD) and measured the reflex size in the post-stimulus trials as difference between post- and pre-stimulus RMS divided by SD of the pre-stimulus trials. Two-ways ANOVA was used to evaluate the effects of unloadings and sites on the reflex size in all muscles. Tukey post-hoc test was used for pair-wise comparisons.
RESULTS: The changes of the NWR induced by unloadings and sites are reported in the figure.
CONCLUSION: Unloadings determine a rearrangement of the NWR receptive fields organization in all muscles of the ipsilateral limb and in VL muscle in contralateral limb. Unloading the body modifies the modular NWR excitability of each muscle according to its role in the postural and balance mechanisms.



*p<0.05, **p<0.05

EFFECT OF SLIP AND ANKLE BRACE ON JOINT MOMENTS AND KINEMATICS DURING A 90° CUTTING MOVEMENT: A PILOT STUDY

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AIM: To verify the effects of slipping with and without an ankle brace on kinematics and kinetics during a 90° cutting movement.
METHODS: A male subject (182.5 cm, 29 year, 101.92 kg) was asked to run at an intensity of 90% and subsequently conduct a 90° cutting movement on a custom-built movable robotic force platform. The subject was equipped with 35 retro-reflective markers which were recorded by an 8-camera motion capture system (Qualisys Oqus, 250 Hz). Force data were sampled at 2000 Hz. The subject was given sufficient time to get accustomed to the movement and it was assured that only a single contact was performed on the platform. Randomly, three conditions of controlled slip in run-up direction were applied immediately after first contact (0, 4 and 8 cm). The experiment was performed on 24 trials with and without ankle brace. After compensation of the inertia effect of the accelerated platform, raw force data were analyzed (MatLab 7.8.0, The MathWorks). The kinematic data were analyzed by a specific motion analysis software (AnyBody Modeling System 4.1.0, AnyBody Technology A/S). The musculoskeletal model is based on one male cadaver measured by the University of Twente (Klein Horsman et al., Clin. Biomech., 2007: 22, 239-247).
RESULTS: The subject demonstrated a considerable increase in the maximal acceleration of the center of mass in gravity direction in the braced trials. The subject showed increased maximum inversion and plantar flexion moments in the no-slip trials. Smaller inversion angles were found for the braced trials and smaller hip flexion angle range during contact phase for the non-braced no-slip trials.
CONCLUSION: These preliminary results suggest that slipping potentially decreases the maximum inversion and plantar flexion moments. Since these moments are likely to be involved in ankle injury it indicates that slipping during early contact can reduce ankle injury risk. With respect to maximum inversion at the ankle this pilot study confirms the restrictive effect of an ankle brace. Regarding the maximum acceleration of the center of mass in gravity direction and hip range of motion during contact further research is needed to investigate if ankle braces indeed change total body loading and kinetics.

Table 1: Maximum acceleration of the center of mass in gravity direction (MAC), maximum inversion moment (MIM), maximum plantar flexion moment (MPFM), maximum valgus moment (MVM), maximum inversion angle (MIA), hip flexion angle range during contact phase (HFR). Data obtained with AnyBody and shown in mean ± SD, n gives number of trials.

Conditions	No slip		8 cm slip	
	No brace (n=7)	**Brace (n=6)**	**No brace (n=6)**	**Brace (n=6)**
MAC (ms^{-2})	8.4 ± 1.3	10.7 ± 0.9	9.4 ± 0.6	10.3 ± 0.7
MIM (Nm)	105.3 ± 28.3	109.3 ± 15.8	70.1 ± 26.8	83.8 ± 21.7
MPFM (Nm)	291.3 ± 52.6	325.8 ± 27.2	235.8 ± 64.9	254.8 ± 37.5
MVM (Nm)	298.0 ± 58.9	357.0 ± 43.9	382.6 ± 53.6	343.6 ± 33.0
MIA (°)	10.50 ± 1.48	9.85 ± 3.27	11.33 ± 2.79	10.37 ± 2.58
HFR (°)	35.5 ± 6.5	42.1 ± 1.6	39.0 ± 1.5	39.5 ± 2.3

TIME OF DAY INFLUENCES POSTURAL STABILITY IN HEALTHY ELDERLY

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AIM: To investigate if postural stability in healthy elderly people fluctuates during the day. METHODS: Center of pressure (CoP) excursion was measured (100 Hz) by force plate analysis (Metitur, Good Balance, Finland) in healthy elderly individuals (n=11, mean age 74.5 years) during narrow static bilateral standing (30-s) with eyes opened. Participants were screened and questioned for sleeping patterns during the night/day and time of potential medicine intake before being tested. None of the participants had a history of orthopedic or neurological disorders, and did not report any fractures in the lower extremities within the last 6 months. Assessments were performed at 09:00 a.m., 12:00 p.m. and 4:00 p.m. on the same day. Resting blood pressure was obtained at each time point to ensure that altered pressure did not affect postural stability. During all force plate recordings subjects were asked to fixate their hands and arms across their stomach, remove their shoes and remain in a static standing position with their eyes focused on a visual target 3 meters away. The illumination level was controlled at 22 lux. Exercise and consumption of products containing caffeine was avoided 2 hours prior to each testing session. CoP ellipse area (AE) calculated as $\pi \cdot SD(x) \cdot SD(y)$ and normalized to the squared body height was used as a measure of postural stability. Statistical comparisons between time points were performed using Bonferroni-corrected Wilcoxon signed rank tests. RESULTS: AE remained statistically unchanged ($p=0.33$) from 09:00 a.m. (37.7±17.4 mm^2/m^2) to 12:00 p.m. (35.8±14.9 mm^2/m^2) and increased ($P=0.006$) at 4:00 p.m. (44.9±16.5 mm^2/m^2). CONCLUSION: The present study demonstrates that time of day influence postural stability in elderly healthy individuals. A 20% increase in AE was observed from noon to late afternoon, indicating a corresponding impairment in postural stability. These findings have important scientific and clinical relevance, as they imply that time of day should be controlled when assessing postural stability in elderly individuals.

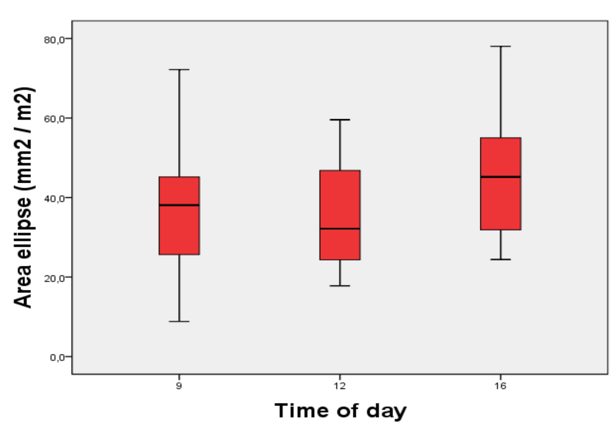

Figure 1: Median, quartiles, and min-to-max range of the CoP ellipse area (mm^2/m^2) at different time points of the day.

INFLUENCE OF VISUAL INPUT IN POSTURAL PERTURBATION IN THE ELDERLY

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AIM: Many changes have been documented in the aging process, such as alterations in conduction and processing responses to perturbed quiet stance. This study analyzed the SEMG response of the bipedal static posture in front of an external mechanical perturbation in Older Men (OM) during two stages of Opened and Closed Eyes (OE and CE), with the objective of compare how the visual input affects the postural response in elderly people.
METHODS: 14 healthy OM volunteer subjects, aged between 65 to 75 years, who haven't suffered central or peripheral alterations, or no controlled systemic damage participated in the study. All subjects gave their informed consent to the study which was approved by the local ethics committee of the Universidad Mayor. The subjects held static bipedal position, isolated from auditive inputs, then were submitted to a sudden forward perturbation equivalent to a 5% of the subject's mass at an interscapular level by a pendulum under the afore mentioned stages. The registered data were the SEMG, (Delsys Bagnoli 8) from the right side of body, from muscles Tibialis Anterior (TA), Gastrocnemious Medialis (GM), Rectus Femoris (RF), Biceps Femoris (BF), Rectus Abdominis (RA) and Longissimus Thoracis (LT). It was used Igor Pro 5.01 software (Wavemetrics) for the data processing and then was synchronized in relation with the time of the perturbation. It was extracted the Timing and RMS from the aforementioned muscles. Statiscal data was analized with SPSS 15.0 software for Windows.
RESULTS: For the analysis of variables, it was used the Kolgomorov-Smirnov test and Wilcoxon test giving the following results:
There is significance difference in timing of TA between both experimental conditions. For all the other variables there were no significance differences.
The activation order in the OE stage was: BF, GM, TA, LT, RA, RF. For the CE stage the sequence was: GM, BF, TA, RA, LT, RF. On the other hand, the RMS value was always bigger in the CE stage than in the OE stage.
CONCLUSION: The activation order of the muscles appears to be of a mixed strategy, and that in the CE stage the muscles are more activated to control the perturbation.

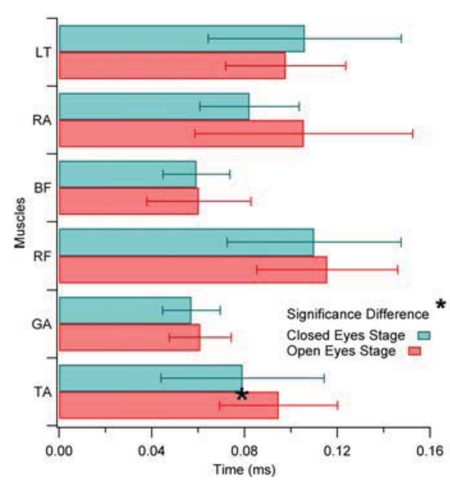

Figure 1: The graph shows the Mean and SD of the activation times of the muscles in both experimental conditions. There is significance difference only in the activation of the Tibialis Anterior.

REDUCED FORCE FIELD ADAPTATION ABILITY IN CHILDREN AFFECTED BY CEREBRAL PALSY

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AIM: This investigation aims to test the possibility to use robotic devices to study the mechanism of sensorimotor adaptation in pediatric subjects affected by hemiparetic cerebral palsy. Previous studies demonstrated how adult stroke patients, after training in presence of a systematic structured disturbing force field, show an “after effect” in catch trials and therefore behave in a similar way to normal subjects as regards their ability to adapt and compensate an external force field. The main question is whether this adaptive capability is preserved in pediatric subjects affected by cerebral palsy.
METHODS: Fifteen subjects volunteerd to participate to the experiment; they were 6 healthy control subjects mean age 9 years (range 8-14), and 9 CP pediatric subjects, age 11 (range 9-14) recruited at the Department of Neurorehabilitation of Bambino Gesù Pediatric Hospital (Rome, Italy). Research was approved by the ethical committee of the Bambino Gesù Hospital and conforms to the ethical standards laid down in the 1964 Declaration of Helsinki. Before starting the protocol, the parents were asked to sign a consent form.
RESULTS: During familiarization (when the robot generates no force) the movement of the CP subjects were more curved, displaying greater and variable directional error; during the force field phase both the groups showed a presence an after effect, but the CP group was unable to perform straight trajectories in order to compensate the force. This suggests that the CP subjects have reduced ability to learn to counteract external force and make greater errors when using this prediction to generate movement. Moreover, a directional analysis of the trajectory kinematics confirms how the control group is able to predict in more accurate way the force field by means of better feedforward control of the inertial anisotropy of the arm.
CONCLUSION: contrarily to stroke subjects, children affected by cerebral palsy seem to have a reduced ability to learn how to compensate an external structured dynamics. Authors suggest the reason is related to incompleteness of the internal model of arm control which impedes CP children to manage the impedance anisotropy during movements.

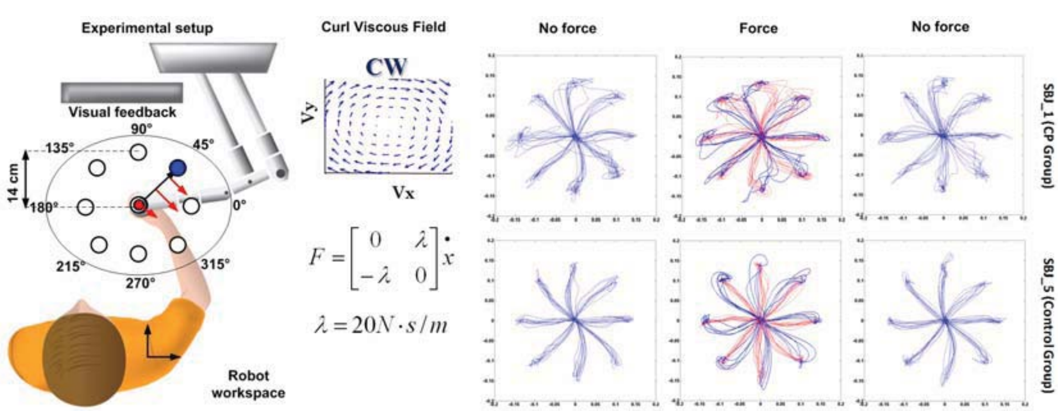

Figure 1: (left) experimental setup and robot generated force field; (right) experimental phases for a CP and a healthy subject.

MEDIUM-LATENCY REFLEX RESPONSE OF FLEXOR CARPI RADIALIS BY STIMULATION OF THE RADIAL

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AIM: We describe a medium-latency response (MLR) in flexor carpi radialis (FCR-MLR) evoked by maximal electrical stimulation of the radial nerve at the spiral grove.
Flexor carpi radialis H reflex stimulated by the median nerve is a well known monosynaptic reflex. But late responses after H reflex and F response are still debated. Medium and late latency responses are generally obtained by stimulating the nerve during the voluntary activity.
METHOD: We stimulated radial nerve from the spiral groove and recorded from the flexor carpi radialis and extensor carpi radialis simultanately by superficial EMG. We recorded a M response from the extensor carpi radialis with F response and a late response from the antagonist flexor carpi radialis.The study included fourteen healthy subjects (5 male and 9 female) (22-45 years).
RESULTS: In 13 subjects we recorded the late response from the flexor carpi radialis by radial nerve stimulation. Latency of the FCR-MLR was 40.6±6.9 ms and amplitude of the response was 513±224 mikrovolt. In 9 of 11 subjects the response disappeared with the use of a splint which restrain the hand extention due to radial nerve stimulation. And in 2 subjects, latency of the response delayed to 43.9±8.6 ms and amplitude of the response decreased to 200±100 mikrovolt. H reflex of FCR by median nerve stimulation was 11.9±2.6 ms.
CONCLUSION: These findings support the idea that the response is due to the stretching of the FCR muscle by the contraction of extensor carpi radialis muscle. We think that the FCR-MLR is similar to medium latency reflex response of soleus elicited by peroneal nerve stimulation.

ROBOT-ASSISTED ACQUISITION OF HANDWRITING SKILLS

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AIM: Handwriting capabilities are important in everyday life. The use of the dominant hand for handwriting may be impaired or prevented in case of stroke or amputation. As a consequence, these subjects are forced to transfer their handwriting skills to their non-dominant hand. Here we investigate whether haptic assistance can be used to facilitate such training, and what scheme of assistance is more effective. We initially focused on normal subjects, aiming at transferring their handwriting skills from the dominant (D) to the non-dominant (ND) hand.
METHODS: Six subjects participated in this pilot study, all right-handed. Subjects were instructed to draw the characters that appeared on a computer screen, while grasping a robot manipulandum. Experiments were organized into blocks of trials, each consisting of drawing five different characters (two times each) of increasing complexity. One experimental session involved 10 epochs, each consisting of a variable number of blocks so that one epoch lasted approximately 5 mins. During the first two epochs, movements were performed, respectively, by the D and the ND hand and the robot generated no forces (baseline phases). In epochs 3-8 (ND hand), the robot generated assistive forces (training phase). In epochs 9-10 (ND hand) assistance was turned off (aftereffect phase). Subjects were assigned to three assistance groups (respectively, 2+2+2 subjects): (i) control: no assistance; (ii) trajectory tracking: the robot generated forces directed toward a target moving along a 'template' trajectory (average trajectory performed during the baseline D phase); (iii) path guidance : forces were directed toward the 'template' path. We looked at the temporal evolution of the figural error (a spatial measure of similarity among complex movements) and trajectory smoothness, per character and assistance type, and at their variability.
RESULTS: In assisted trials, both performance and its variability decrease (more in the path guidance condition; see Figure). As regards the aftereffect, performance improvements are apparent in assisted but not in control trials. However, it is still unclear which scheme of assistance is more effective.
CONCLUSION: Preliminary results suggest a short-term benefit of assistance in accelerating learning. Further experiments will be needed to assess retention and generalization to other characters and different scaling.
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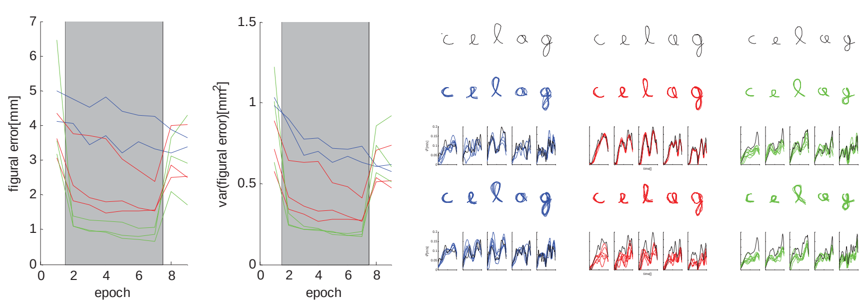

HIGH DENSITY EMG DATA OF NORMALLY LIMBED AND TRANSRADIAL AMPUTEES

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AIM: Upper limb prosthetics currently used in clinical settings have limited functionality. Using conventional myoelectric control systems with one or two electrode sites, prosthetic users often have the ability to perform open and close motions of the myoelectric hand. Pattern recognition myoelectric control systems provide prosthetic users with the ability to control multiple functions of the prosthetic device. Classifiers within these systems recognize the specific muscle activity patterns produced during different movement contractions and select the appropriate output function (i.e. open or close the hand). A limited number of studies have included amputee subjects in their investigations on pattern recognition myoelectric control. The purpose of this work was to determine if transradial amputees could produce distinct and repeatable muscle activation patterns required for successful pattern recognition myoelectric control. Both congenital and traumatic transradial amputees and normally limbed subjects were tested using a high density EMG system.

METHODS: Eight normally limbed subjects and four amputee subjects participated in this study. A high density EMG system (TMS International) was used for data collection. Twelve wrist and hand motions were performed during testing and were classified as gross, medium and fine movements. Normally limbed participants performed 20, 5-second contractions of each movement for a total of 240 contractions. The testing protocol for amputee subjects varied because each individual presented a unique case. Up to 64 channels of EMG were used with the high density EMG system and the electrodes were placed in a grid formation over the forearm to collect as much data from a large surface area. The areas on the forearm that experienced muscle activity during given movements were illustrated in energy maps. Channel reduction on the high density EMG data was conducted to determine the classification accuracies with a clinically acceptable number of electrodes. Ten electrodes that provided the best information for pattern recognition were selected for analysis.

RESULTS: Classification accuracies were generally greater for normally limbed subjects with an average of 80.02 ± 5.52% compared to an average of 66.39 ± 14.26 % for transradial amputee subjects. The classification accuracies were also generated from more classes of data for normally limbed subjects than amputee subjects. Classification accuracies were higher for all subjects when only subsets of the strongest motions were induced. By reducing the number of movements included in the analysis, the chance of misclassifications was decreased, and therefore allowed for better classification accuracies (92.63 ± 2.54% for normally limbed subjects and 94.22 ± 2.66% for amputee subjects. Channel reduction was performed for each subject's EMG data to determine which 10 electrodes provided the best information for pattern recognition control. The mean change in classification accuracies were 10.72 % (p=0.001) and 3.48% (p=0.369) for normally limbed subjects and amputee subjects respectively.

CONCLUSION: The results from this work support the hypothesis that amputee subjects are able to elicit distinct and reproducible patterns for a subset of movements. In addition, classification accuracy does not diminish when data from a clinically acceptable number of electrodes were used in the analyses.

NEUROMUSCULAR ELECTRICAL STIMULATION IS AN EFFICIENT COMPLEMENT TO VOLUNTARY EXERCISE FOR IMPROVING MUSCLE PERFORMANCE IN BOTH HEALTHY HUMANS AND ATHLETES

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Since the 18th century, it is commonly acknowledged that muscle contraction can be evoked by applying an electrical current to the neuromuscular system. In both healthy and impaired muscles, this artificial method of muscle activation is called neuromuscular electrical stimulation (NMES) since contractile activity results from direct excitation of the intramuscular nerve branches. The pioneering work of the Russian researcher Yakov Kots demonstrated that NMES is suitable for improving maximal voluntary strength. The present lecture attempts to provide an overview of the current knowledge of changes in muscle performance after multiple sessions of NMES. We will focus on interests and limitations of NMES training programs in both healthy individuals and competitive athletes. Typical NMES resistance exercise is performed under isometric conditions and involves the application of stimuli delivered as intermittent high frequencies trains (> 40-50 Hz) through surface electrodes. It is noteworthy that the quadriceps femoris is the muscle most often stimulated. The primary outcome measure to assess the effectiveness of NMES training is the use of maximal voluntary isometric (and/or dynamic) strength. Strength gains ranging from ~1% to ~55% have been reported according to the stimulated muscle, the selected stimulation parameters (pulse duration, waveform…) as well as the number and duration of training sessions. Interestingly, it has been demonstrated that the strength increments are related to the level of electrically evoked force. Given that the subject's tolerance of the electric current strongly determines the force evoked by NMES, there is a considerable inter-individual variability in NMES response. A recent systematic review also provided evidence that NMES is not more effective than traditional voluntary resistance training. Nevertheless, the underlying mechanisms responsible for strength improvement are similar between these two modalities so that neural adaptations mainly occurred during the first weeks of training while muscular changes took part in the further increase in strength. Considering that NMES is characterized by a specific motor unit recruitment pattern and is associated with a greater metabolic demand as compared to voluntary actions, it has been proposed that both modalities should be combined in sports training. Growing evidence is emerging illustrating the potential beneficial effects of a short-term NMES training program in both individual (swimming, tennis, weightlifting…) and team sport athletes (basketball, volleyball, ice hockey, rugby…) as indicated by the significant improvement in both vertical jump and sprint performance. Overall, it appears that NMES is an efficient modality to enhance muscle performance, even in highly trained individuals. In addition, a typical NMES training session is usually shorter (~15 minutes) than traditional voluntary exercise. However, it should be remembered that NMES is often limited by pain and/or discomfort during stimulation so that athletes are often unwilling to use this training modality. Given that NMES is mainly delivered under isometric (i.e., non-specific) conditions, chronic administration of NMES could be harmful for dynamic movements requiring high levels of coordination. Recent studies have also reported deleterious side-effects such as muscle damage and delayed-onset muscle soreness after a single bout of NMES. On that basis, one could suggest that NMES should be mainly incorporated into the preparatory season of competitive athletes even though further studies are needed to design the optimal periodization of NMES training.

POLYELECTROMYOGFRAPHIC INVESTIGATION OF PARAVERTEBRAL MUSCLE ACTIVATION PATTERNS DURING LOCOMOTION

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AIM: The purpose of this study was to describe the caudal to cranial alteration of paravertebral muscle activation patterns during locomotion as well as further alteration due to walking velocity.
METHODS: We examined 56 healthy subjects (27 females, age 35.7 ± 12.8 years, 29 males, age 35.1 ± 12.2 years) while walking on a treadmill at randomly assigned speeds of 2, 3, 4, 5, and 6 km/h. Paravertebral muscle activity was detected by using rows of 16 monopolarly connected surface electrode strips (H93SG8, Arbo, Germany) at both sides of the spine with an inter-electrode distance of 2.5 cm. The most caudal electrode was placed at L5 level. Spatial filtering was applied by consecutive bipolar calculation of neighboring electrode signals from caudal to cranial, resulting in 15 bipolar channels at each side. Strides were time normalized and grand averaged rms curves were calculated. Furthermore, normalized rms curves and side differences were calculated to identify co-ordination patterns.
RESULTS: The typical three-phasic activation pattern that is showing amplitude peaks at each heel strike vanishes towards cranial regions. Furthermore, the most prominent peak at contralateral heel strike also decreases from caudal to cranial, but increases again in the mid-thorakal region. Together with walking velocity peak amplitude levels increase as well. From low to medium speeds the low level amplitudes during stance phases are characterized by an asymmetric behavior with larger amplitudes during contralateral stance phases. This effect is being balanced at higher walking speeds. Co-ordination patterns were also characterized by two overlapping effects: first the more cranial the electrode is located the less phasic the activation patterns are, second this effect is again damped at higher walking speeds. Side differences are also subject to change according to electrode localization and walking speed. At low speeds side differences are biphasic with predominant contralateral activity during the respective stance phases, again more distinct for caudal electrodes. This characteristic increases its frequency towards a four-phasic pattern at higher speeds, starting with contralateral predominance at each heel strike, switching to exceeding ipsilateral activation at early stance phase that finally changes back to contralateral predominance during late stance phase. The ipsilateral difference during early stance phase is more pronounced in cranial regions whereas the contralateral predominance at late stance phase is observed best in caudal regions.
CONCLUSION: Paravertebral activation patterns during locomotion are considerably altered according to electrode position and walking speed. Increase of walking speed not only simply increases strain level in terms of adding amplitude offset. The increase of dynamic demands at higher speeds causes distinctive adaptations which depend on vertebral level as well.

TRUNK MUSCLE CO-ORDINATION WHILE CARRYING LOADS

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AIM: Human's bipedalism is unique among mammals. It enables us to use our arms and hands for any kind of manipulative task. If loads have to be carried trunk muscles simultaneously have to accomplish the static demand of adequate trunk stabilization and the dynamic requirements during locomotion. This study was performed to get more insight into how trunk muscles are organized during such combined tasks with special focus on their expected behavior patterns according to the well established trunk muscle systems.
METHODS: Three groups of healthy subjects were examined (*I* n= 39, age 24.4 ± 4.7 years, *II* n= 42, age 28.2 ± 11.2 years, *III* n= 43, age 27.5 ± 9.6). While walking on a treadmill we applied graded loads at different positions: *I* in front of the body, *II* at body axis, and *III* behind the body. Loads of 5 kg, 10 kg, and 15 kg were carried by the subjects with their hands (*I*, *II*) or through waistcoats (*III*). Surface EMG was taken from five trunk muscles: rectus abdominis muscle (ra), oblique internal and external abdominal muscles (oi, oe), lumbar multifidus muscle (mf), and the longissimus part of erector spinae muscle (es). Grand averaged curves were calculated and time independent (mean rms level, ratio, normalized maximum-minimum range) as well as time dependent parameters (rms curves, normalized curves: co-ordination pattern) were extracted. Analysis was particularly focused on the identification of muscle or task dependent patterns.
RESULTS: Mean rms levels increased for all muscles during *I* and *III*, except mf which decreased during *III*. *II* virtually did not alter mean rms levels. As expected, the ratio of both back muscles increased during *I*. During *II*, according to the negligible changes of their rms levels, ratios of all investigated trunk muscles remained almost unchanged. Surprisingly, during *III* ra, oe and es muscles increased their ratio while oi and mf were characterized by the opposite effect. Normalized range decreased for mf and es during *I* but remained virtually unchanged for the other muscles and during *II* for all muscles. During *III* except ra which increased its range all other muscles showed reduced range levels.
The observed changes of the time independent parameters were caused by differently organized processes. Two examples will be outlined here: For oi the increase of its mean rms level during *I* was caused by a general amplitude offset with almost no change of its co-ordination pattern. In contrast, its mean rms increase during *III* was characterized by a proportionally larger rise of its low level amplitudes compared to the increase of its amplitude peaks. For mf the rms increase during *I* was organized similarly to what could be observed for oi during *III*. During *III* the distinctive three phasic pattern of mf, which is characterized by amplitude peaks at every heel strike was damped, particularly by a reduction of the peak amplitudes at heel strike.
CONCLUSION: The investigated trunk muscles sometimes do follow their expected behavior patterns but those patterns are not consistently observable. Therefore, a general muscle or task related pattern could not be identified within this investigation. This argues for functional diversity of the investigated muscles which are able to adapt their behavior according to specific task related demands resulting in stabilizing as well as mobilizing characteristics.

COMPARISON OF LEG MUSCLE ACTIVITY IN LOKOMAT WALKING, TREADMILL WALKING AND LEVEL WALKING IN CHILDREN

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AIM: Walking is the preferred movement strategy in humans, at least over short distances. Due to the importance of walking, different therapy strategies are used for gait rehabilitation: walking with robotic aid, treadmill, and overground walking. In adults data comparing these different approaches exist but not in children. Therefore, the aim of this study was to provide insights in time-distance parameter and muscle activity differences due to these three gait modalities in children.
METHODS: Eleven healthy children (5 girls, 6 boys) between 6 and 10 years walked in the driven gait orthosis pediatric Lokomat®, on a treadmill and over ground with slow but typical rehabilitation speed of 0.5m/s; in overground walking an additional measurement at normal speed was performed. The muscle activity of the mm. biceps femoris, rectus femoris, vastus medialis, gastrocnemius lateralis and tibialis anterior was measured with surface EMG. Gait events were assessed bilaterally by foot switches.
RESULTS: The step length was smallest in treadmill walking, in-between in robotic and slow walking and highest in normal walking. The cadence was lowest in robotic, in-between in treadmill and highest in overground walking. The same ranking was found in the muscle activity amplitude, except in the m. biceps femoris where the EMG activity was much increased in the Lokomat condition, especially during loading response (Fig. 1).
CONCLUSION: The muscle activities of most muscles are only little affected by the gait modality except for the biceps muscle. Differences can be explained either by the unloading in the Lokomat or by changed velocities. However, children seem to act against the Lokomat with their hamstrings and hence using an abnormal activation pattern. Therefore, further research in healthy and impaired children is recommended as well as improvements in Lokomat movement control.

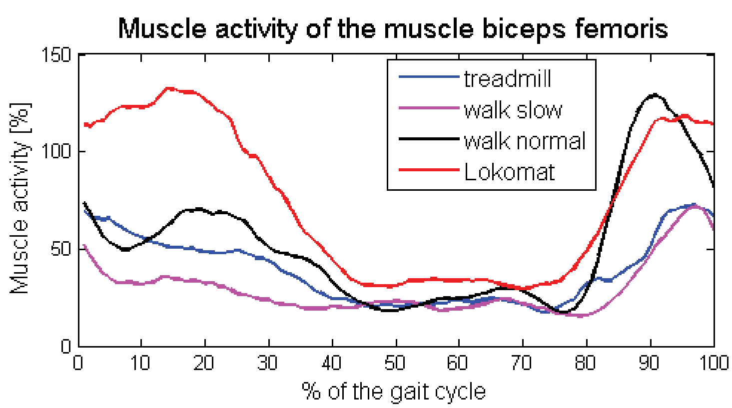

Figure 1: Activity of m. biceps femoris during different gait modalities in healthy children (n=11).

AN EASY AND ROBUST METHOD FOR ECG ARTIFACT ELIMINATION OF SEMG SIGNALS

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AIM: Electrocardiographic (ECG) artifacts, i.e. ventricular activations are often unavoidable contaminations of Surface EMG (SEMG) measurements. They share a broad frequency range with SEMG signals so that frequency filtering algorithms will affect SEMG signals considerably. We tried to develop an easy and robust method to remove such artifacts without altering the content of the SEMG signal.
METHODS: During routine SEMG investigations an additional trigger channel was set up which recorded ECG activity directly along heart axis. Prior to any specific calculation all measured channels were corrected for possible amplitude offsets. The trigger channel was used to reliably detect ventricular activity, i.e. the top dead center of the R wave without SEMG interference. Subsequently, these positions were used to calculate templates for every single measured SEMG channel. The template had a width from -100 ms to +100 ms around the identified time point. The templates were then subtracted form the SEMG signals using detected ventricular events. To avoid alterations of the SEMG signal at the margins of the subtracted template a cosine weighting function resulting in zero amplitude levels was used at the margins of the template.
RESULTS: Depending on SEMG activation characteristics a minimum of 20 ventricular events seems to be necessary. Intense SEMG activity requires more ventricular events to ensure undisturbed templates. Considering these prerequisites, the algorithm is able to virtually completely remove ECG artifacts from SEMG signals. Since templates are calculated separately for each channel they are robust against differently appearing ventricular vectors and time shifts in comparison to the trigger channel.
CONCLUSION: The presented algorithm enables a fast and low-loss decontamination of SEMG signals. Since the templates were calculated without using any filters the quality of the templates can possibly be further increased by low pass filtering of the template if that is thought to be of relevance. This would not affect the frequency content of the SEMG signal.

SCAPULAR MUSCLE ACTIVATION-BALANCE DURING SELECTED REHABILITATION EXERCISES

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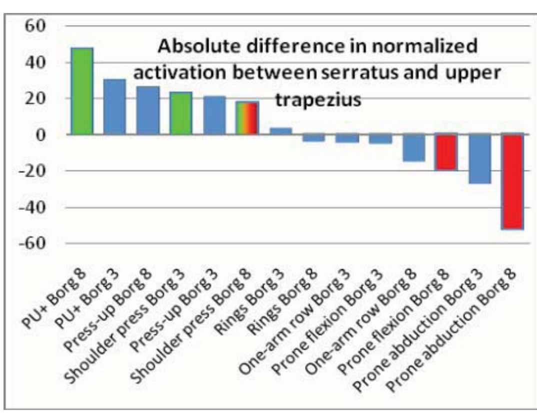
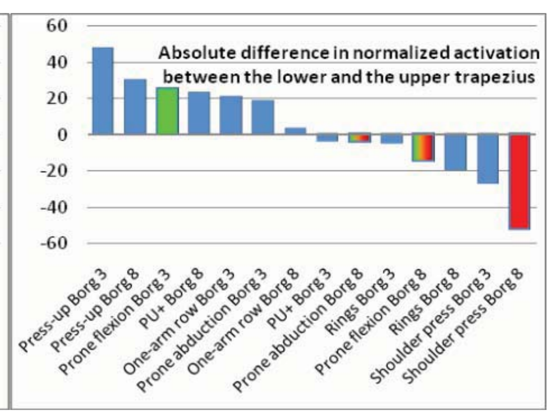
AIM: Shoulder function requires both strength and fine-tuned muscle coordination. Therefore, it is relevant to investigate which strengthening exercises can induce high levels of muscle activation in the lower trapezius and/or the serratus anterior muscle compared to the upper trapezius. The aim of this study was to determine the level of muscle activation of scapular muscles with surface EMG during 7 selected strengthening exercises in women.
METHODS: A group of 17 women (29 ± 7.2 yrs; 168 ± 6,3 cm, 62.7 ± 11.1 kg) with primarily sedentary jobs performed the following training exercises for the muscles around the shoulder girdle: (1) shoulder press, (2) one-arm rows, (3) press-up, (4) prone abduction, (5) prone flexion, (6) ring fallouts and (7) push-up plus. Each exercise was performed at loadings corresponding to level 3 and level 8 on the Borg CR10 scale. Surface EMG from the upper, middle and lower trapezius, serratus anterior, mid-portion of the splenius capitis, medial deltoid and infraspinatus was measured.
RESULTS. *Upper trapezius (UT):*The exercises with the lowest UT muscle activation were ring fallouts (10% ± 2% at Borg 3) and press-ups (14% ± 2% at Borg 3 and 21% ± 3% at Borg 8). The level of UT muscle activation was highest during the prone flexion (76% ± 5%), prone abduction (68% ± 6%) and shoulder press (60% ± 6%) performed at Borg 8 intensity.
Serratus anterior(SA): For the SA muscle activation was highest during the shoulder press (78% ± 6% at Borg 8 and 61% ± 5% at Borg 3) and push-up plus (72% ±6% at Borg 8).
Lower trapezius (LT): The LT showed the highest muscle activation during prone flexion (72% ± 5% at Borg 8 and 70% ± 5% at Borg 3) and prone abduction (70% ± 4% at Borg 8).
DISCUSSION: If the purpose of using a given exercise is changing the muscle activation balance with strengthening exercises it is very relevant to compare the activation of specific muscles during the specific exercises. Below the graphs show absolute difference in normalized emg between a) SA and UT and b) LT and UT. Graph a shows that it is possible by using the exercises Push-up plus at Borg 3 + 8 and Press-up at Borg 8 to primarily recruit the SA over UT and graph b shows that by using the exercises Press-up at Borg 3 + 8 and Prone flexion at Borg 3 to recruit LT over UT.



a



b

CENTRAL ACTIVATION AND MUSCLE CONTRACTILE PROPERTIES DURING PROLONGED INTERMITTENT MAXIMAL EXERCISE

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AIM: This study investigated the relative importance of central and peripheral factors contributing to neuromuscular fatigue development in human lower limb muscles during prolonged intermittent maximal exercise, by superimposing a transcranial magnetic stimulation (TMS) on the voluntary contraction.
METHODS: 11 healthy recreationally active young volunteers (24±1.4y, 73±3.4kg, 175±1.7cm, 10male, 1 female) performed brief ankle dorsiflexions of various strengths before (PRE) and after (POST) intermittent 2s-maximal voluntary contractions (MVC) until volitional fatigue or inability to maintain force of more than 50% initial MVC. Suprathreshold single pulse TMS was performed during each PRE- and POST- and each 10th-maximal contraction. The contraction force was recorded in parallel with the surface compound motor evoked potentials (MEP) from the antagonist muscles tibialis anterior (TA) and soleus (SOL). Central activation was quantified by the changes in MEP parameters, cortical silent period duration (SP, ms) and the voluntary activation (VA, %). Peripheral fatigue was assessed by the changes in the time-amplitude parameters of the TMS-evoked twitch forces. Non-parametric tests were used for statistical analysis of the data.
RESULTS: The subjects completed 98±10 (mean±SEM) exercise repetitions prior to fatigue. Significant attenuation of MVC force (-39±4%, p<0.0001), RMS EMG amplitude (TA: -25±2%, p=0.003; SOL: -26±5%, p=0.004) and VA (-39±10%, p=0.004) accompanied by a significant MEP facilitation (TA: 49±17%, p=0.026; SOL: 47±22%, p=0.016) and SP prolongation (TA: 29±7%, p=0.002; SOL: 23±6%, p=0.004) were observed at fatigue (Fig. 1). TA MEP amplitudes were significantly attenuated POST vs PRE (-16±4%, p=0.016) while POST SOL MEP size and the SP duration for both muscles were recovered to PRE values. POST MVC (-16±3%, p=0.003) and VA (-5±2%, p=0.050) were lower than PRE as were the estimated resting twitch (-33±7%, p=0.006) and the normalized peak relaxation rate (-29±8%, p=0.013). TA MEPs remained depressed throughout the 5min recovery period.
CONCLUSION: Prolonged intermittent maximal exercise induced deficits in both peripheral muscle contractility and neural drive (adequacy and/or efficiency of the motor cortex output). The relative contribution of central and peripheral factors to muscle fatigue development in ankle dorsiflexors resembles that observed for upper limb muscles.

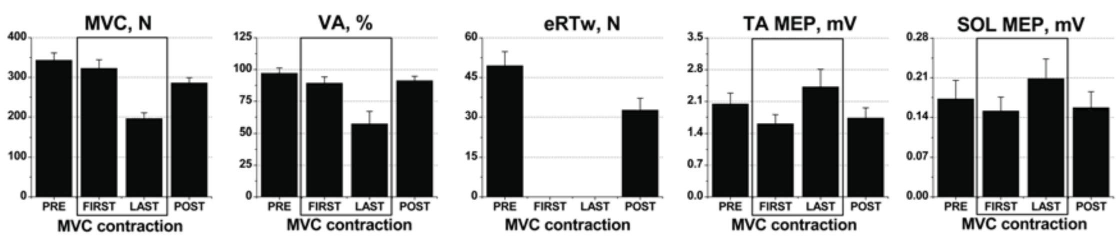

Figure 1: Voluntary activation (VA) declined in parallel with potentiation of motor potentials (MEP) evoked by cortical stimulation in tibialis anterior (TA) and soleus (SOL) muscles at fatigue. Recovery of POST VA and MEP amplitude towards PRE values was faster than that of estimated resting twitch (eRTw) and normalized muscle peak relaxation rate.

POSITION OF THE CENTRE OF PRESSURE IN YOUNG ADULTS DURING POSTUROGRAPHY

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AIM: In clinical posturography all data and results are expressed in averaged positions of the Centre of Pressure (CoP), wich means that it is not possible to determine the exact position of the CoP and its displacement in the Base of Support (BoS) during quiet standing. Several studies have investigated the behaviour of CoP migration and oscillation, however the mean position of the the CoP is not known and therefore can't be used as an evaluation parameter to quantify improvements after applied therapies.
METHODS: Sixty healthy subjects from both genders, aged between 18 and 21 years old, participated in the study. Mean height was 1.70 (±0.03) and all had normal Body Mass Index (BMI).
All participants stood on an oscillograph (ArtOficio) and held quiet stance in bipedal position, to register the normal displacement of the CoP in the postero anterior (P-A) direction in the BoS. Then the subjects were asked to oscillate at maximum range without loosing their balance in the sagital plane without lifting their foot or toes to determine the longitud of the BoS expressed as a percentage. Each recording was made in 90 seconds. Data analysis consisted in determining the BoS as the distance between heel and toe as 0 to 100% respectively, then combine both conditions recordings to normalize the normal posturography as the displacement of the CoP in the BoS from 0 to 100%
RESULTS: As described in the graph the mean location of the COP_{P-A} was in the 40.32% of the BoS.
CONCLUSION: The position of the centre of pressure is behind the centre of the BoS in the Postero- Anterior Direction.

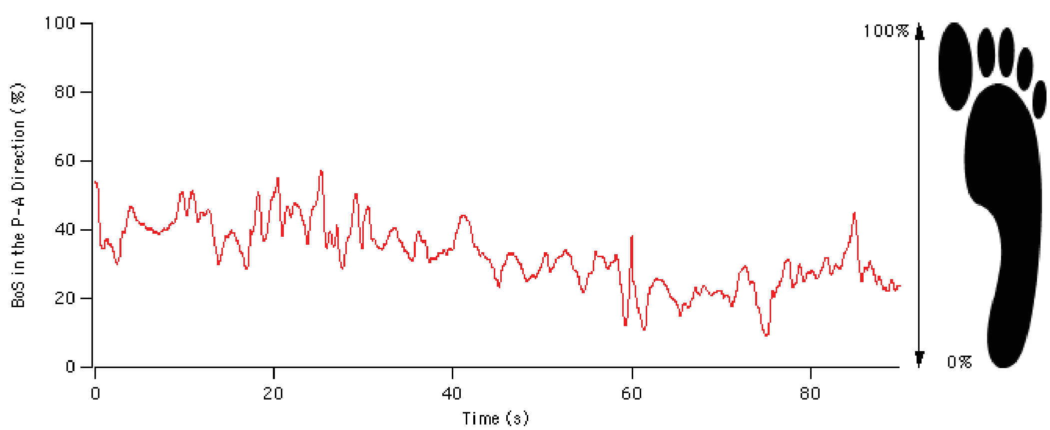

Figure 1: This graph illustrates the relation between the BoS $_{P-A}$ distance and the displacement of the $CoP_{P-A.}$ The footprint illustrates the P-A (heel to toes) longitude of the BoS expressed as percentage.

BILATERAL PUSHING FORCE SYMMETRY AND MUSCLE ACTIVATION OF MOVEMENTS USING SLING SUSPENSION SYSTEM

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AIM: This study aimed to investigate the magnitude and variability of pushing force in the dominant and non-dominant sides in healthy subjects. As well, the associations between bilateral pushing force and muscles activation between limbs and trunk was been discussed.
METHODS: Ten young healthy volunteers (mean age twenty-three years old) were participated in this study. Surface EMG system and two load cells were used to collect muscle activation (triceps brachii, rectus abdominis, gluteus medius) and bilateral pushing forces simultaneously. The movements included components of core muscle stability and symmetric limb movements. Symmetry index was indicated the absolute difference of mean force. We designed five movements with sling suspension system to represent upper limbs (1&2), lower limbs (3&4) and whole body (5) movement respectively. (Fig 1)
RESULTS: Movement 2 and 4 were progressive movement and had worst symmetry index during posture maintenance stage. The whole body muscles activation appeared more in movement 5. Large abdominis activation existed in all movements.
CONCLUSION: Asymmetry pushing force appeared more in progressive movement such as movements 2 & 4. Combined movements produced more whole body muscles activation as appeared in movement 5.
ACKNOWLEDGEMENT: We would like to thank the financial support from National Science Council, Taiwan, NSC- 98-2410-H-037-013.

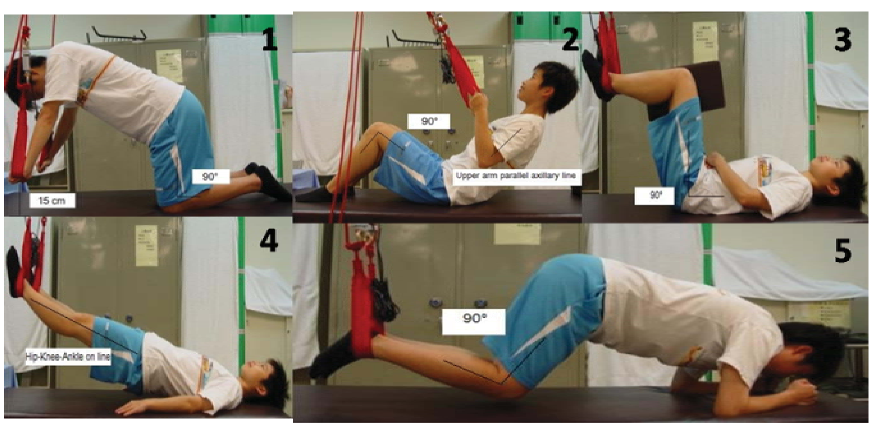

Figure 1: Five movements with sling suspension system

KNEE JOINT EFFUSION AFFECTS KNEE MOTION AND QUADRICEPS MUSCLE FUNCTION DURING GAIT IN MODERATE KNEE OSTEOARTHRITIS

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AIM: This study tested whether knee joint effusion presence alters sagittal plane knee motion and periarticular muscle function during gait in those with moderate knee osteoarthritis (OA).
METHODS: Twenty asymptomatic subjects and 34 patients with knee OA participated after giving informed consent. Patients were divided into knee effusion (n=20) and no knee effusion (n=14) groups based on the brush test. After standard skin preparation procedures, bipolar skin surface electrodes (Ag/AgCl-interelectrode distance 20mm) were placed over the lateral and medial gastrocnemius, vastus lateralis and medialis, rectus femoris and the lateral and medial hamstrings. During self-selected walking, electromyograms (EMG) were recorded at 1000 Hz using an AMT-8™ EMG measurement system (Bortec Inc.). An Optotrak™ motion capture system (Northern Digital Inc.) recorded thigh and lower leg motion. Euler rotations were employed to derive sagittal plane knee angles during gait. EMG waveforms were corrected for subject bias, full wave rectified, low-pass filtered (Butterworth, Fc-6Hz) and amplitude normalized to maximal effort voluntary isometric contractions. All waveforms were time normalized to the gait cycle. Quadriceps, gastrocnemius and hamstring strength was measured from torques produced against a Cybex™ dynamometer during maximal effort voluntary isometric contractions and normalized to body mass (Nm/Kg). Principal Component Analysis extracted EMG and motion waveform features that together explained more than 90% of the variance in the original data set. *PC-Scores* were computed for each original waveform. Analysis of variance models tested for main effects (group, muscle) and interactions. Bonferonni post hoc testing was employed (α=0.05).
RESULTS: Hamstring and gastrocnemius muscular activation features (PP1, PP2 and PP3) that explained >90% of the waveform variability in each muscle group were not influenced by the presence of effusion ($p>0.05$). For the quadriceps musculature, the overall magnitude (PP1) and mid-stance magnitude in comparison to both early and late periods of the gait cycle (PP2) were greater in the presence of effusion ($p<0.05$). No muscle strength differences were found between knee OA groups ($p>0.05$). Asymptomatic individuals were stronger for the quadriceps and gastrocnemius only ($p<0.05$). Greater knee flexion during late stance (PP3) was maintained for those with effusion compared to the no effusion and asymptomatic controls ($p<0.05$).
CONCLUSION: These results support the hypothesis that knee effusion in those with moderate knee OA altered sagittal plane knee motion during mid to late stance with a simultaneous increase in quadriceps activation. Given that there were no strength differences between the two moderate OA groups, two potential mechanisms for the quadriceps activity increase are i) to counter moments due to increased knee flexion and ii) to provide stiffness to increase dynamic joint stability during impact loading and single leg stance. These novel findings shed light on the effects of knee effusion on periarticular muscle function during gait in a moderate knee OA population that have not been previously established and have implications for increased metabolic demand and joint loading.
ACKNOWLEDGEMENT: Nova Scotia Health Research Foundation and Killam for funding.

ELECTROMYOGRAM NORMALIZATION: AN INVESTIGATION OF MAXIMAL VOLUNTARY ISOMETRIC CONTRACTION EXERCISES IN MODERATE KNEE OSTEOARTHRITIS

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AIM: The aim was three fold, i) to determine whether a single exercise produced a maximal activation for each of the quadriceps, hamstrings and gastrocnemius musculature ii) to determine whether maximum activations occurred for the same exercise between asymptomatic individuals and individuals with knee OA and iii) to quantify the level of agonist and antagonistic activity.
METHODS: Sixty-eight asymptomatic individuals and 68 participants with moderate medial compartment knee OA based on radiographic evidence and functional ability were recruited. All participants provided written consent. After standard skin preparation, bipolar surface electrodes (Ag/AgCl-interelectrode distance 20mm) were placed over the lateral and medial gastrocnemius, vastus lateralis and medialis, rectus femoris and the lateral and medial hamstrings. Subjects performed a series of eight maximal effort voluntary isometric exercises held for 3-seconds each including 1) knee extension at 45 degrees in sitting (KE45), 2) from position 1) a combined knee extension/hip flexion (KEHF) 3) knee flexion at 55 degrees in sitting (KF55), 4) knee extension at 15 degrees in supine (KE15), 5) knee flexion at 15 degrees in supine (KF15), 6) plantar flexion at neutral in supine (PF), 7) plantar flexion in standing (PFStand) and 8) knee flexion at 55 degrees in prone (KF55Prone). Electromyograms (EMG) were recorded at 1000 Hz using an AMT-8™ EMG measurement system (Bortec™ Inc.), corrected for subject bias, full wave rectified and low-pass filtered (Butterworth, Fc-6Hz). Maximal amplitudes were identified for each exercise using a 100ms moving-average technique and were normalized to the absolute maximum level of activity recorded from all exercises. Exercises producing the maximum amplitude for a given muscle were identified and frequency counts recorded. A two-factor mixed model with repeated measures Analysis of Variance tested exercise and group main effects and interactions for the normalized amplitudes for each muscle (α=0.05). Bonferonni post hoc testing was performed on significant results.
RESULTS: For each muscle group, a single exercise did not induce a maximum activation for every participant. No agonist/antagonist activation differences were found between groups for exercises that elicited the highest percentage of maximum ($p>0.05$). KE45 and KE15 elicited the majority (82%) of maximum quadriceps activations for both groups. For the hamstring muscles, the majority of subjects from both groups obtained a maximum activation during KF15 and KF55Prone (86%), where only 12.5 % of all individuals obtained a maximum from KF55. Different exercises produced maximum activity for lateral hamstrings compared to medial hamstrings. PFStand recorded the greatest number of maximal gastrocnemius activations (57%).
CONCLUSIONS: No single exercise produced a maximum activation for all muscles, emphasizing the importance of an exercise series in this testing. Given that group differences in the maximum normalized values from these exercises as well as antagonistic activity were not found, these findings provide an important first step in standardizing normalization protocols for electromyographic studies of neuromuscular function in individuals with knee OA.
ACKNOWLEDGEMENT: Nova Scotia Health Research Foundation and Killam for funding.

THE EFFECTS OF MUSCLE FATIGUE ON THREE-DIMENSIONAL FORCE STEADINESS DURING ISOMETRIC TRUNK EXTENSIONS

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AIM: Muscle fatigue impairs muscle coordination and increases force fluctuations during steady contractions. Fatigue related changes in muscle coordination might affect all the three-dimensional components of the force outcome, especially in complex muscle groups, e.g. trunk muscles, where such changes may affect the spine stability. The purposes of this study were (1) to quantify the three-dimensional components of force fluctuations during isometric trunk extensions before and after fatigue, and (2) to verify the influence of trunk agonist and antagonist muscles coordination in such fluctuations.
METHODS: Fifteen healthy subjects (12 male, 3 female, age: 23.8 ± 4.75 yr) performed two series of sustained isometric trunk extensions (12 sec) against a three-dimensional force sensor, approximately over T2, at different force levels (2.5, 5, 10, 20, 30, 50, 70 and 80 %MVC) before and after a 60% fatiguing isometric contraction until exhaustion. Surface EMG signals from six trunk muscles (LO longuissimus, MF multifidus, IL iliocostalis, IO internal oblique, EO external oblique, and RA rectus abdominis) and from the rectus femoris muscle (RF) were recorded using bipolar electrodes. A 2-way ANOVA (Force level×Fatigue) was used to check for changes on each of the three components of force fluctuations (measured as the standard deviation of force) and the RMS values of all EMG signals.
RESULTS: The standard deviation of all force components increased significantly with increasing force level ($P < .001$), as well as the RMS EMG values of all measured muscles, with the exception of the RA muscle. Moreover, fatigue resulted in an increase of all the components of force fluctuations ($P < .05$), accompanied by an increase in agonist muscles activity (LO and MF, $P < .05$, and a trend for IL, $P = .12$) and a decrease (IO, $P < .05$, and a trend for IL, $P = .15$) or no change (RA) in the already low antagonist activity.
CONCLUSION: This study showed increased variability of all the three-dimensional force components with increasing force levels of trunk extensions, i.e. a direct relationship between the signal amplitude and the amount of force fluctuations. The increased agonist muscle activity induced by fatigue, especially at high force levels, was not compensated by the antagonist muscles, leading to higher force fluctuations and impairments in trunk stability.

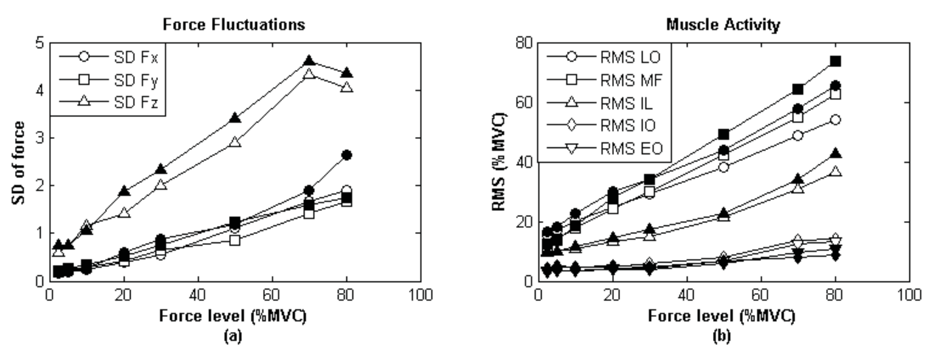

Figure 1: A progressive increase in the level of isometric trunk extensions results in (a) higher force fluctuations and (b) higher agonist muscles activity (LO, MF and IL). Fatigue (filled symbols) induced even higher agonist muscle activity.

EFFECT OF MAXIMAL ISOKINETIC TRAINING ON ISOMETRIC STRENGTH AND RATE OF FORCE DEVELOPMENT

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AIM: To verify the effects of isokinetic maximal eccentric training on isometric torque (T_{ISO}), peak rate of force development (RFD) and time to achieve the RFD (RFD_{TIME}).
METHODS: Eighteen physically active males, were randomly divided in a control group (CG, n=6: mean ± SD: 24±2 years, 183.6±3.7 cm and 87.4±11 kg) and a training group (TG, n=12: mean ± SD: 22.5±3 years, 178.4±6.6 cm and 77.8±10 kg). Firstly, all subjects were familiarized to isometric and isokinetic contractions. At least five days after this, 5-seconds maximal isometric contractions for the knee extensors were required at 75° (0°=full extension). After this, an 8-weeks maximal knee extensors eccentric training (180°.s^{-1}, three sessions/week) was conducted with the TG, while the CG did not perform any systematic resistance training during 8 weeks. After these 8 weeks, the re-test was performed with the CG and TG, similar to the protocol applied before the training. Knee extensors T_{ISO}, RFD (derived as the average slope of the moment-time curve [Δtorque/Δtime] over time), and RFD_{TIME} were analyzed by a 2 x 2 (group and training) ANOVA. Tukey HSD test was used to post-hoc comparison of means, if applicable, with significance level set at $p<0.05$.
RESULTS: T_{ISO} (Figure 1A) and RFD (Figure 1B) presented significant increase after the training period for TG ($p<0.05$), with no changes in RFD_{TIME} ($p>0.05$) (Figure 1C). This means that subjects after the eccentric training were able to produce higher torque levels, and beside this, there was an increased capacity to generate explosive force output. However, changes in RFD were credited to higher power output, not to faster power output. CG presented no significant differences between any condition within the group, No significant differences were found between groups.
CONCLUSION: The maximal eccentric training changed the power output characteristics of isometric contractions, increasing the T_{ISO} and, consequently the RFD. The training was not effective to increase the velocity in which the maximal torque was produced.
ACKNOWLEDGEMENT: We would like to thank FAPESP and CAPES for financial support.

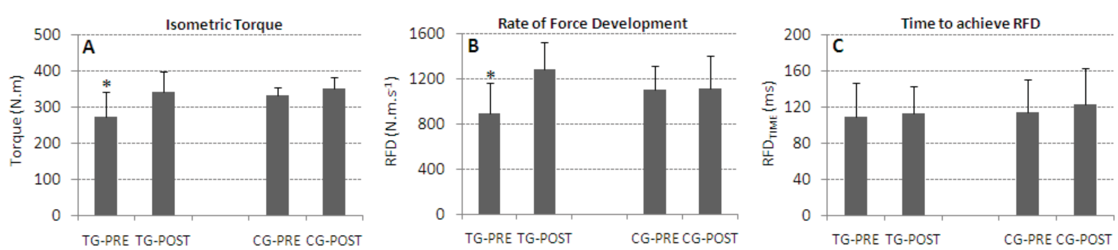

Figure 1: Isometric peak torque (Figure A), rate of force development (Figure B, RFD) and time to achieve RFD (Figure C, RFD_{TIME}), for the training group before (TG-PRE) after 8 weeks of maximal isokinetic training (TG-POST), and for the control group before (CG-PRE) after 8 weeks with no training (CG-POST). * denotes significant difference in relation to TG-POST ($p<0.05$).

PHYSICAL WORKLOAD ON NECK SHOULDER AND UPPER EXTREMITY IN VARIOUS TYPES OF OCCUPATIONAL WORK

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AIM: Physical workload, in terms of extreme postures, repetitive movements, high muscular load and lack of recovery, are known risk factors for developing upper extremity musculoskeletal disorders (UEMSDs). The prevailing methods for assessing physical workload – questionnaires and observer ratings – may however not be sufficiently valid and precise for deriving quantitative exposure-response relationships as a base for prevention. The aim was to explore the correlations between, and range of, various exposure measures, derived from technical measurements recorded at the workplaces for a wide variety of work.
METHODS: Electrogoniometers were used for recording of wrist flexion(+)/extension(-), inclinometers for head flexion(+)/extension(-) and upper arm elevation, and EMG on the forearm extensors and the trapezius muscles. Muscular activity was normalized to EMG during maximal voluntary contractions (MVE). Various percentiles of the angular, angular velocity, and muscular activity distributions, and for EMG also the fraction of time with muscular rest/recovery, were used to describe the load. About 40 types of work, repetitive as well as varied, in industry and office, were recorded, for about 15 subjects in each work.
RESULTS: Many exposure measures, especially adjacent percentiles, and all movement measures, were highly correlated. For postures, distant percentiles showed low correlation. Thus, for the wrist and head, e.g. the 90th and the 10th (for the head the 1st) percentiles seem relevant for describing flexion and extension, respectively. Upper arm elevation may be suitably described by the 99th percentile. For each body part, one velocity measure (e.g. the 50th percentile) may be sufficient to describe the movements. Muscular rest/recovery and peak load (90th percentile), although somewhat correlated, are relevant to include as two different exposure dimensions, since they represent conceptually different patho-mechanisms. For all exposure measures there were great variations due to work: wrist: flexion -18° to 32°, extension -49° to -20°, movements 1.4 to 54 °/s; head: flexion 9° to 63°, extension -39° to 4°, movements 2.3 to 33 °/s; arm: elevation 49° to 124°, movements 3.0 to 103 °/s; forearm extensors: muscular rest/recovery 0.2% to 23% of time, peak load 3.4% to 41% MVE; trapezius: muscular rest/recovery 0.8% to 52% of time, peak load 3.1% to 24% MVE.
CONCLUSION: Technical measurements provide quantitative and objective data and are practically applicable for whole-day ambulatory recordings in almost all types of work. The multidimensional character of the exposure – extreme postures and movement, as well as muscular rest/recovery and peak load – has to be considered. The presented measures of the main physical workload risk factors for developing UEMSDs are appropriate candidates for describing exposure-response relationships in epidemiological studies.
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EFFECT OF KNEE JOINT ANGLE ON MECHANICAL AND ELECTROPHYSIOLOGICAL RESPONSES OF HUMAN KNEE FLEXOR MUSCLES

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AIM: To determine, at 3 different knee angles, Biceps Femoris passive contractile characteristics and muscle stiffness responses before and after the execution of knee flexion maximal voluntary contractions (MVC).
METHODS: 16 healthy active individuals (14 males and 2 females; mean $\pm$ SD age and body mass of 24.4 $\pm$ 5.6 years and 75.5 $\pm$ 8 kg respectively) were secured in the prone position on an isokinetic dynamometer for isometric MVC knee flexion at joint angles of 0 (leg fully extended), 45 and 90^0, during which torque and electromyography (EMG) from the Biceps Femoris was recorded. Before and after MVC's dampened oscillations of the Biceps Femoris were obtained in response to both a passive maximal twitch and a mechanical impulse using Tensiomyograph (TMG) and Myometer systems respectively. These oscillations were recorded and expressed as: contraction time (ms) for peak amplitude displacement and stiffness ($N.m^{-1}$) for TMG and Myometer respectively. For estimation of TMG and Myometer reliability 10 of the subjects returned on a separate day to repeat these 2 measures at all 3 joint angles.
RESULTS: MVC Torque declined ($p<0.01$) from 0, 45 to 90^0 knee angles (100.3 $\pm$ 20.8, 82.0 $\pm$ 16.8 and 57.4 $\pm$ 15.02 $N.m^{-1}$) with significant ($p<0.01$) differences in rate of force development (Figure 1). TMG contraction time showed an increase ($p<0.01$) from 0 to 45^0 (Figure 2A) whereas muscle stiffness declined ($p<0.01$) across all 3 angles (Figure 2B). Interday reliability (ICC) at 0, 45 and 90^0 for TMG and Myometer was 0.781, 0.57 and 0.36 and 0.74, 0.56 and 0.69 respectively. No differences where shown in electrical mechanical delay whereas EMG amplitude declined ($p<0.01$) by ~35% at 90^0 compared to the other 2 angles (0, 45 and 90^0: 690.2 $\pm$ 209.5, 673.5 $\pm$ 280.4 and 449.4 $\pm$ 211.9 mV).
CONCLUSION: Muscle stiffness measurement was effective in explaining the change in torque and rate of force development at all 3 knee joint angles likely by changing the length tension relationship. Also, at greater knee angles there may be neuromuscular as well mechanical mechanisms responsible for the observed torque decline.

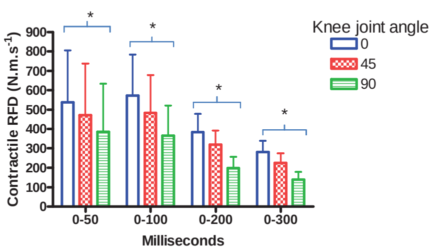

Figure 1: Rate of force development *p<0.01.

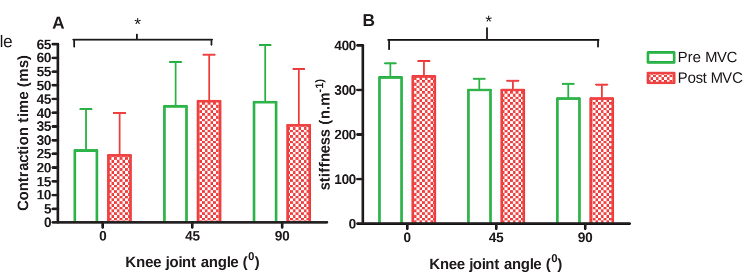

Figure 2: (A) Twitch response peak amplitude displacement (B) muscle stiffness. *p<0.01.

FUNCTIONAL CHANGE OF SIT-TO-STAND MOVEMENTS IN SUBJECTS WITH SPASTIC CEREBRAL PALSY FOR 1-3 YEARS

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AIM: The purpose of this study was to describe functional change of Sit-to-Stand (STS) movements of children with spastic cerebral palsy (CP).
METHODS: This research study utilized longitudinal-sectional design for 1-3 years. Twenty-one children with spastic CP (11 males and 10 females), aged 3 years 2 months to 14 years 2 months, took part in the study. In the analysis, firstly, pictures of the subjects' STS movements were taken regularly from the side with one digital video camera. Based on our previous study, the subjects' STS movements were classified into 4 aggregate groups (Large trunk movement: LTM, buttocks forward movement: BFM, and upper extremities dependence type in sitting or standing: UEDSI or UEDST). The first classification of STS movements was baseline; the functional change of STS movements was investigated within each group.
RESULTS: The baseline classification of STS movements were: LTM (n=9), BFM (n=8), UEDSI (n=3) and UEDST (n=1). Eight pattern changes of STS movements were observed. Four of those pattern changes were as follows: the change from BFM to LTM (n=4), from LTM to BFM (n=2), from LTM to UEDSI (n=1), and from LTM to BFM to UEDST (n=1). The change from BFM to LTM was observed under 8 years old. Conversely, the other 3 changes (the change from LTM to BFM, from LTM to UEDSI, and from LTM to BFM to UEDST) tended to be observed over 8 years old.
CONCLUSION: These findings indicate that there is a relation between the functional change of STS movements and age in spastic CP.

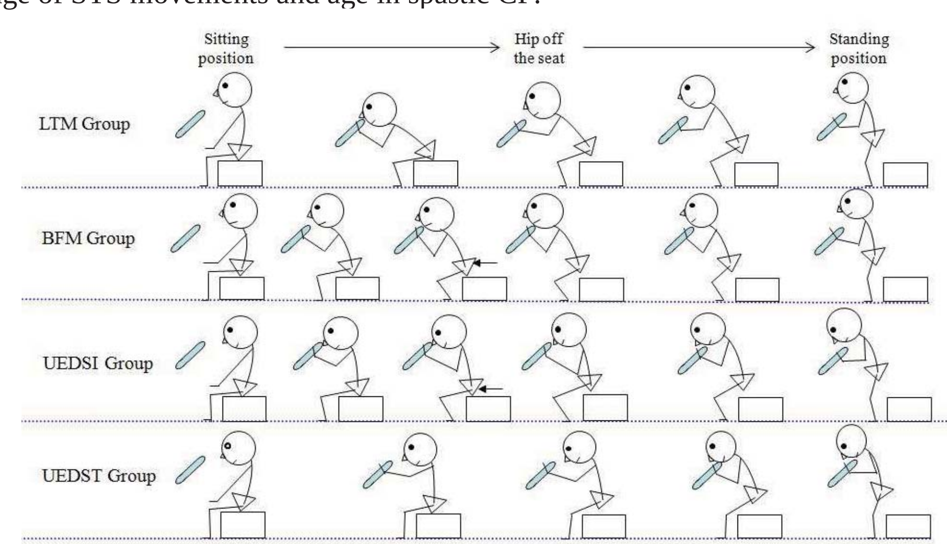

Figure 1: Four aggregate groups of CP STS movements
(Published in NeuroRehabilitation, 2009)

EMG AND BIOMECHANICAL ANALYSES AS EFFECT MEASURES IN TRAINING INTERVENTIONS FOR NECK SHOULDER PATIENTS

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AIM: Unspecific neck/shoulder pain is a frequent complaint in industrialized countries and particularly often reported among female workers with high intense monotonous repetitive work based on biomechanical exposure assessment (5). None the less there is a lack of knowledge regarding these workers' functional impairment and even more important regarding interventions that will improve function. Several studies have documented decreased maximal voluntary contractile strength (MVC) of the neck/shoulder muscles (4) but more detailed information is requested to tailor intervention for functional improvement.
METHODS: In a case-control and subsequent randomized controlled study with intense physical exercise training among trapezius myalgia cases, EMG was recorded from several shoulder muscles together with kinetics and kinematic variables (2; 3). These measures were obtained during simulated work tasks as well as standardized test.
RESULTS: During the work tasks the cases activated their trapezius muscle significantly more compared with the controls although only minor difference were found in the hand movements (3). The tests showed cases to have impaired static as well as dynamic muscle strength and that this was to be explained by decreased activation of the painful muscle. With 10 weeks of strength training the myalgia group normalized towards the healthy control values regarding static and dynamic strength as well as muscle activation (1).
CONCLUSION: Intense physical training exercise was shown to improve the functional capacity of neck/shoulder muscles. These changes occurred concomitantly with reductions in neck/shoulder pain

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CHANGES IN MOTOR CONTROL STRATEGIES AND MUSCLE METABOLISM IN TRAPEZIUS MYALGIA

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AIM: To study motor control in subjects with (MYA) and without (CON) trapezius myalgia during standardized tests as well as during repetitive and stressful work tasks either in a lab setting or during real working life together with muscle metabolism.
METHODS: 43 MYA and 19 CON were studied in the lab setting (1; 3) while 20 MYA and 20 CON were studied during and after a full 8-hour workday (2). Further, a number of standardized tests were performed to assess functional capacity and motor control. At rest and during work tasks the trapezius muscle was measured using EMG, microdialysis, and NIRS. Further, subjective pain ratings were scored (VAS).
RESULTS: The maximal muscle capacity was impaired in MYA compared with CON in the painful trapezius muscle in particular during dynamic performance. In the lab stetting with standardized repetitive work tasks EMGrms in %MVE (Maximal Voluntary EMG-activity) was significantly higher among MYA than CON (11.74 +/- 9.09 vs. 7.42 +/- 5.56%MVE). MYA versus CON demonstrated lower muscle blood flow and higher lactate and pyruvate concentrations. NIRS showed similar initial decreases in oxygenation with work in both groups, but only in CON a significant increase back to baseline occurred during work. VAS score at rest was highest among MYA and increased during work tasks, but not for CON. During the 8-hour workday no corresponding EMG differences were found between MYA and CON. Regarding the metabolites similar differences were found for pyruvate but not for lactate. Interestingly, muscle blood flow was higher in MYA compared with CON. MYA reported higher pain intensity throughout the day, and interstitial serotonin was higher compared with CON (before work: 10.6+/-10.8 vs. 2.2+/-1.2nM; after work: 9.2+/-8.3 vs. 1.5+/-2.9nM).
CONCLUSION: Pain induced changes in motor control in the myalgic trapezius may only be revealed in response to standardized functional tests or work tasks. Work performed at the worksite may be performed by other than the painful muscles supporting the pain adaptation model. However, such adaptation did not relief pain in MYA and increased levels of nociceptive substances were identified compared with CON.
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METHOD FOR CONTROL OF ELECTRICAL STIMULATION FOR ASSISTING OF THE WALKING IN HEMIPLEGIC PATIENTS

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AIM: The task of the research was to develop the real-time control for multi-channel electrical stimulation that assists the walking of hemiplegic patients. The method selected was the rule-base control which uses signals from inertial sensors mounted on the paretic leg, and outputs step-like profiles of the intensities of electrical stimulation.
METHODS: We applied inductive learning method using the following: data collected from inertial sensors mounted on the thigh, shank and foot, and force sensing resistors on the non-paretic leg while walking assisted with the special walking assist (Walkaround®) and muscle activation profiles as outputs. The activation profiles were estimated by using two sets of information: the recruitment determined in a hemiplegic subject during electrical stimulation and optimal joint torques determined by dynamic optimization that used the cost function which minimizes the tracking errors with the penalty function of minimum activity of muscle set at 10% from the maximum. The controller was tested using data collected from six subjects walking slowly: v = 0.6 m/s.
RESULTS: The stimulation profiles for one subject are presented in Fig. 1 along with the resulting trajectories of the ankle and knee while walking. The stimulation frequency was selected to be f = 25 pulses per second, and the charge Q = IT is the product of pulse amplitude (I) and pulse duration (T). The maximum pulse intensity was set to be 50 mA. The step-like activation profiles that were synthesized, considering the properties of musculo-tendonal systems and inertia, result with smooth movement as it can be seen from the trajectories.
ACKNOWLEDGEMENT: This work was partly supported by the Ministry of Science and Technology of Serbia, Belgrade

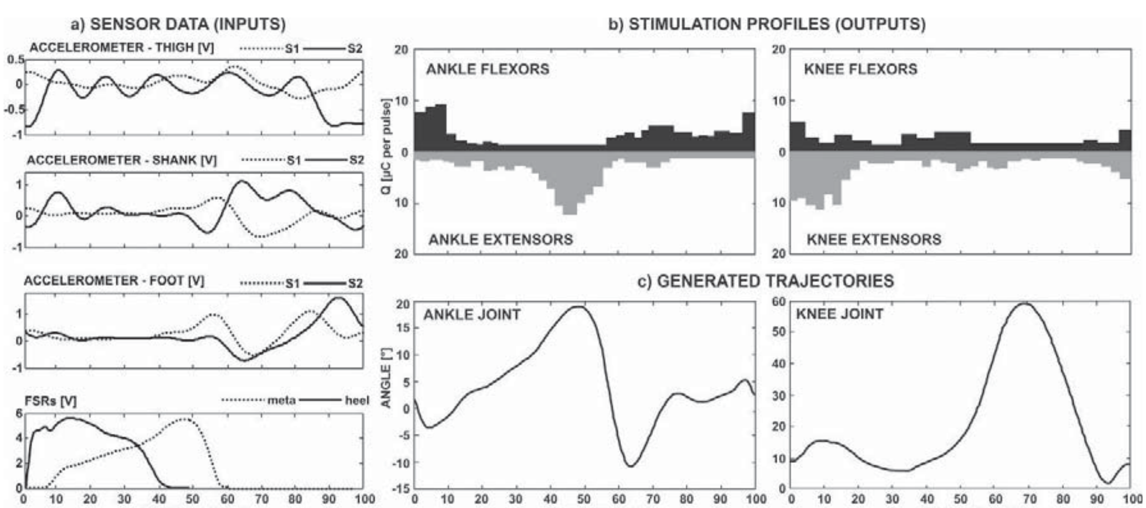

Figure 1: The intensities of electrical stimulation (top panels, right) for generating the trajectories that are healthy-like (bottom panels, right). The input signals that are used as input in the rule-based controller are in left panels.

EFFECTS OF WINDOW LENGTH AND CLASSIFICATION ACCURACY ON THE REAL-TIME CONTROLLABILITY OF PATTERN RECOGNITION MYOELECTRIC CONTROL

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AIM: The relationship between classification accuracy, controller delay, and controllability of pattern recognition myoelectric control systems is not well defined. The aim of this study was to further investigate these relationships.
METHODS: Electromyographic (EMG) data were collected from four Ag-AgCl gelled Noraxon Dual Electrode (Noraxon, Scottsdale AZ, USA) pairs which were placed approximately equidistantly around the circumference of the forearm of 13 able-bodied control subjects. The gain on each channel was set to make full use of the analog-to-digital conversion range, and each channel was band-pass filtered between 20-500 Hz and sampled at 1000 Hz using a Measurement Computing 1616 FS 16-bit A/D converter. A pattern recognition system (time domain features classified by a linear discriminant classifier) was trained to recognize forearm pronation and supination, wrist flexion and extension, hand open and close using 12 seconds of training data (4 repetitions of 3 second contractions) for each motion. Twelve seconds of testing data to determine classification accuracy were collected for each motion. A real-time performance test in a virtual environment was performed as analysis window lengths (epochs) were varied between 50 and 550 ms. The real-time test required a subject move a virtual hand from 6 different starting postures to a target posture in three-dimensional space. Starting postures were chosen so that subjects had to move each degree of freedom through its full range of motion. Subjects were also required to correct for any unintended motions while attempting the target postures.
RESULTS: Figure 1 displays the relationship between classification accuracy and completion rate as a function of analysis window length. Classification accuracy increases with longer window lengths (more EMG data) as expected. Motion completion rate increases with window length and peaks at 250 ms before decreasing. The data was fit to a general linear model (GLM), which used subject as a random effect, window length as a fixed effect and classification accuracy as a covariate. The results of the GLM indicated that classification accuracy and window length both had significant effects on motion completion rate (**P<0.001**). The coefficients of the GLM showed that each percentage increase in classification accuracy produced a 2.8% increase in completion rate.

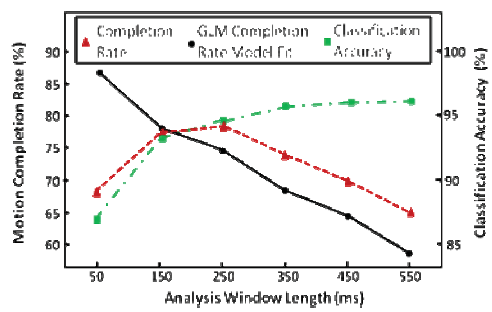

Figure 1: Classification Accuracy, Completion Rate and GLM model fit of completion rate as a function of window length. Results are averaged across all subjects and trials.

CONCLUSION: Classification accuracy and window length have a significant impact (p<0.001) on controllability. Optimization of this relationship (250 ms for this study) will result in a more controllable and clinically viable system.

STRATEGIES TO REDUCE MYOELECTRIC PATTERN RECOGNITION SENSITIVITY TO ELECTRODE SHIFT

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AIM: Pattern recognition based myoelectric control systems are often studied in controlled laboratory settings but several obstacles remain before they are clinically viable solutions. One important obstacle is maintaining the performance of the pattern recognition algorithms in the presence socket/residual limb misalignment (electrode shift). This research used a high-density electromyographic (EMG) recording system to investigate measurement configurations to improve system robustness in the presence of misalignments.
METHODS: Two 8x7 EMG electrode grids were constructed and attached to a TMS International Refa 128 HD EMG acquisition system such that interelectrode spacing was 1 cm between adjacent electrodes in the grid. Two control sites were located by palpating the flexor and extensor muscle groups. The grids were placed over the located muscles such that the columns of eight electrodes each were arranged longitudinally down and the rows containing seven electrodes each were arranged in the transverse direction. The top of each grid was located proximal to the elbow (approximately 2 cm from the elbow joint). Data were collected from the 112 electrodes simultaneously as subjects completed the following motions: wrist flexion, wrist extension, forearm pronation, forearm supination, hand open and hand close. A pattern recognition system which consisted of a concatenated time-domain and autoregressive coefficient feature set extracted from 150 ms analysis windows and classified by a linear discriminant analysis classifier was trained and tested for varying socket/residual limb misalignments. A number of different bipolar EMG configurations were created in software to investigate the effect of electrode size (simulated by averaging a number of adjacent monopolar electrodes), interelectrode spacing, and electrode orientation.
RESULTS: Figures 1a, 1b, and 1c display the results for electrode size, interelectrode spacing and electrode orientation respectively. An ANOVA statistical model was created and showed that all three effects were significant ($p < 0.05$).
CONCLUSION: Wider inter-electrode spacing, larger electrodes and transverse electrode configurations provided a significantly ($p<0.05$) more robust pattern recognition systems in the presence of electrode shifts. It is likely that the larger electrode pick-up area relative to the misalignment distance was the cause of the improved performance.

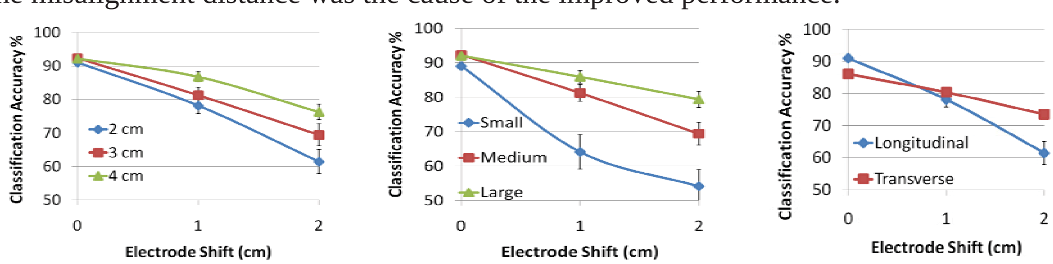

Figure 1: Classification Accuracy as a response with increasing electrode shift distances. The results are shown for a) different interelectrode spacing using medium sized longitudinal channels, b) different simulated electrode sizes using an interelectrode spacing of 3 cm, and c) different electrode orientations using a medium sized electrode. All results are averaged over 7 subjects and 4 different shift directions (proximal shift, distal shift, medial shift and lateral shift).

THE EFFECT OF 5 DAYS THETA BURST STIMULATION ON CORTICOSPINAL EXCITABILITY IN PATIENTS WITH ALS AND HEALTHY CONTROLS

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AIM: In ALS, excess extracellular glutamate appears to render cortical cells hyperexcitable and vulnerable to cell death. Continuous theta burst stimulation (cTBS) by transcranial magnetic stimulation can induce a change in motor cortex excitability that theoretically may antagonize this glutamate-mediated toxicity. In this study we explored the dose response effect of five days cTBS on corticospinal excitability in patients with ALS and healthy controls.
METHODS: cTBS was applied over the left primary motor cortex in ten patients with ALS and eight healthy controls on five consecutive days (Monday-Friday). The effect was measured every day and on the Monday and the Friday the week after. The primary outcome measure was the corticospinal excitability as the amplitude of a single pulse motor evoked potential (MEP), measured in the APB muscle. Besides, we determined the resting motor threshold (RMT). Short interval intracortical inhibition (SICI) and facilitation (ICF) were assessed using a paired pulse protocol.
RESULTS: A single session of cTBS decreased the single pulse MEP in healthy controls, but not in patients. The RMT, SICI and ICF did not change in either group. Five consecutive days of cTBS resulted in a significant decrease of the single pulse MEP in patients, but not in healthy controls (see Figure 1). The RMT increased in both patients and healthy controls. The SICI and ICF did not change in both patients and healthy controls. However, an independent t-test confirmed a significant difference in the baseline value of SICI between the groups. In the second week, the single pulse MEP seemed slowly to return to baseline in patients.
CONCLUSION: We confirmed that cTBS can be safely applied and repeated over five consecutive days in patients with ALS and in healthy controls. Our results suggest that there is a possibility to decrease corticospinal excitability in patients with ALS, by means of repeating cTBS over consecutive days. The effect of repeated cTBS in healthy controls is not clear yet.

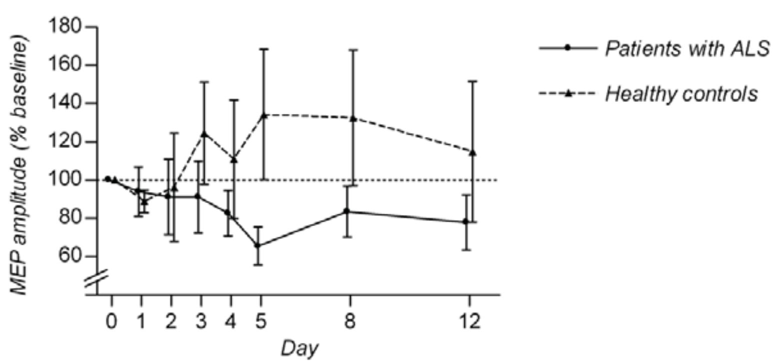

Figure 1: Single pulse MEP amplitude expressed as percentage of baseline for both the patients with ALS (solid line) and healthy controls (dotted line). Data shown as mean ± SEM.

IS AUTOMATED LOCOMOTOR TRAINING BETTER THAN STRENGTH TRAINING AFTER INCOMPLETE SPINAL INJURY?

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AIM: To compare changes in several walking-related and physiologic outcome measures due to automated body weight supported treadmill training (BWSTT) with the Lokomat (Hocoma AG, Switzerland, Figure 1) and lower extremity strength training in subjects with chronic incomplete spinal cord injury.
BACKGROUND: Several studies have shown that walking speed improved due to (automated) BWSTT in chronic iSCI subjects. However, it is unclear whether such an improvement is due to the specificity of the training (directly aimed at stimulating central pattern generators in the lower spinal cord) or whether similar improvements might occur due to a less specific training, such as strength training of the lower extremity. It is also unclear what aspects of walking other than gait speed improve due to automated BWSTT.
METHODS: Chronic (> 1 year) sensory-motor incomplete spinal cord injured subjects with poor walking ability were recruited and each subject performed 16 units of automated BWSTT and 16 units of lower extremity strength training within two months (order of interventions was randomized). Several walking-related measures such as walking speed, adapted walking, gait analysis and efficiency, corticospinal conductivity, foot placement reaction time, Berg Balance Scale and questionnaires that assess independence and risk of falling were collected at baseline, after 4 weeks of intervention and at the end of the intervention. The 10 meter walking test was assessed weekly.
RESULTS: The study is ongoing and preliminary results of at least 5 subjects will be presented at the meeting.

Figure 1: Lokomat (Hocoma AG, Volketswil, Switzerland).

ESTIMATING NERVE EXCITATION THRESHOLDS TO CUTANEOUS ELECTRICAL STIMULATION BY FINITE ELEMENT MODELING COMBINED WITH A STOCHASTIC BRANCHING NERVE FIBER MODEL

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AIM: Cutaneous surface electrical stimulation at painful intensities activates both non-nociceptive Aβ-fibers and nociceptive Aδ- and C-fibers. The present study proposes a finite element (FE) model of the extracellular potential and stochastic branching fiber model of the afferent fiber excitation thresholds (derived from McNeal 1976).

METHODS: The FE model described the electrical field in four conductive horizontal layers; stratum corneum, epidermis, dermis, and hypodermis. The modeled electrical field was used to estimate the excitation threshold in Aβ-fibers terminating in dermis and Aδ-fibers terminating in the epidermis (figure 1). The perception thresholds after stimulation through 11 circular electrodes with diameters ranging from 0.2 mm to 20 mm were modeled and assessed experimentally on the volar forearm by an adaptive two-alternative forced choice algorithm to validate the modeled perception thresholds.

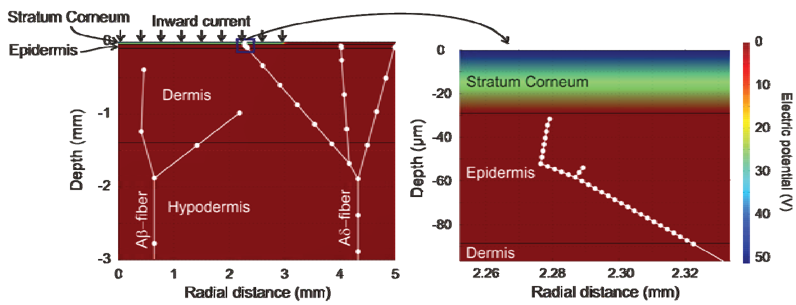

Figure 1. The electric potential of the cutaneous layers were modeled by a FE model and used to estimate the individual excitation threshold of 2300 Aβ- and 1000 Aδ-fibers, which were generated as stochastically branching fibers. The Aβ-fibers terminated in the dermis whereas the Aδ-fibers pertruded into the epidermis while stripping the myelinization.

RESULTS: The FE model showed that the current density was highest for smaller electrodes and decreased downwards through the skin. The current density was highest at the center of small electrodes (diameter < 3 mm) at the depth of the dermoepidermal junction whereas the current density was highest at the edge for large electrodes (diameter > 3 mm). The excitation thresholds of the Aδ-fibers were lower than the excitation threshold of Aβ-fibers when stimulation was applied with small electrodes, but not when stimulation with large electrodes was applied (figure 2).

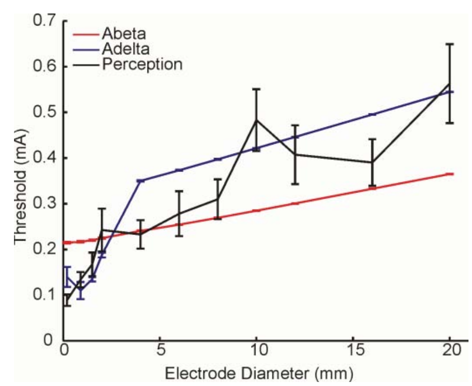

Figure 2. The experimentally assessed perception threshold followed the lowest excitation threshold of the modeled afferents.

CONCLUTION: The study showed the feasibility of combining a FE model and a stochastically branching nerve fiber model when estimating neural excitability after electrical stimulation. The model confirms that preferential excitation of Aδ-fibers may be achieved by cutaneous small electrode stimulation due to higher current density in the dermoepidermal junction.

SULMA-PERIODS OR BURSTS – WHICH RISK ESTIMATING PARAMETERS SHOULD BE USED IN ANALYSES OF LONG TIME EMG RECORDINGS?

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AIM: Sustained trapezius muscle activity has been shown to increase the risk of neck and shoulder pain: number of eight-minute-periods with <u>su</u>stained <u>l</u>ow-level <u>m</u>uscle <u>a</u>ctivity >0.5% EMG_{max} (SULMA-periods, (1)), and more than 70% of burst time, i.e. working time above 2% EMG_{max} (2). Both studies consider the occurrence of continuous muscle activity above a certain discrimination level. The aim of this study was to evaluate the effect of data processing procedures on similar measures of sustained trapezius muscle activity.
METHODS: Full-day bilateral EMG from upper trapezius muscles were collected from forty subjects (17 men, 23 women, median age 22 years, range 22-26), who had just left technical school and started mainly as hairdressers, electricians and students. Number of periods and total duration of activity above discrimination levels 0.5, 1 and 2% EMG_{max} were retrieved from data processed by each of six Root Mean Square (RMS) window lengths. Several analyses of patterns of activity and rest were made, and this paper presents some basic descriptives concerning total duration of muscle activity.
RESULTS: The static muscle activity level (APDF) was 0.3% EMG_{max} and the mean burst time was 65%. The total time of muscle activity depended largely on the discrimination level (Figure: panel A compared to B). For all discrimination levels, the total activity time increased with an increasing RMS length, and became larger when the demands for a minimum period duration were relaxed (figures A and B).
CONCLUSION: Thus, muscle activity patterns extracted from EMG are highly sensitive to the data processing procedure and we suggest that a standardized approach should be developed so that future studies will be comparable.

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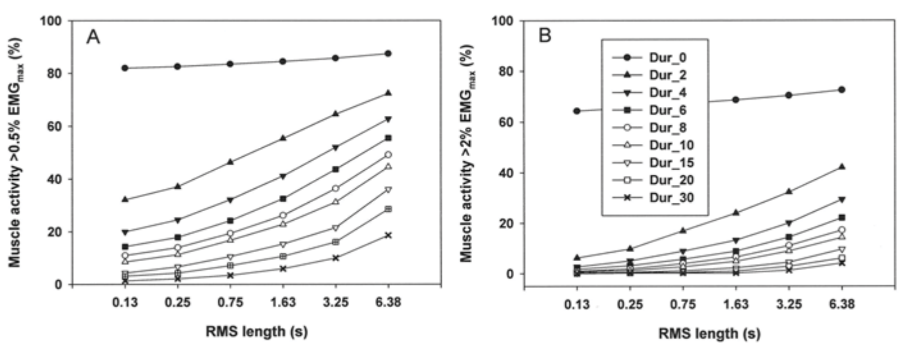

Figure. Relative total time of muscle activity periods >0.5% EMGmax (A) and >2% EMGmax (B) dependent on minimum duration of periods (0-30 min) and RMS length for right upper trapezius muscle (N=40)

RELATIONSHIP BETWEEN CHANGES IN TRACKING PEFRORMANCE, AND TIMING AND AMPLITUDE OF BICEPS AND TRICEPS EMG FOLLOWING TRAINING IN A PLANAR ARM ROBOT IN A SAMPLE OF PEOPLE WITH POST-STROKE HEMIPLEGIA

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AIM: To investigate changes in motor performance (target tracking), timing and amplitude of biceps and triceps muscle activity (EMG), in a sample of people with upper limb hemiplegia following stroke, before and after training in a planar robot.

METHODS: In a planar robot, in which the arm was supported by a hinged arm-holder and constrained to move in 2 dimensions, five chronic stroke participants practiced a subset (chosen to be appropriate to ability) of nine tracking tasks in which trajectory (orientation and length), speed and resistance to movement were varied during 18 (n=3) and 25 (n=2) one-hour training sessions. During tracking, electrical stimulation (ES) (40Hz biphasic, fixed amplitude, variable pulse-width; 0-300µs) was delivered via a commercially available CE marked stimulator using surface self-adhesive electrodes to the triceps muscle. Iterative Learning Control (ILC) algorithms were applied to reduce tracking error on consecutive trials by adjusting the pulse width and timing of ES. Immediately before training and after session 18, EMG and tracking performance (without ES) data were recorded during nine tasks. EMG signals were recorded from seven muscles including triceps and biceps using Noraxon Dual Ag-AgCl snap electrodes positioned according to SENIAM guidelines. EMG signals for each muscle were also recorded during maximum voluntary isometric contraction (MVIC). EMG signals were sampled at 1500Hz, amplified x2 at the electrodes to reduce the signal to noise ratio. Further EMG signal processing was performed using Matlab (7.2.0.232). Data were zero-phase filtered, using a fourth order Butterworth filter with passband 10-500Hz, then full wave rectified and smoothed using a moving average filter with 0.1s window. EMG data was normalised using the MVIC.

RESULTS: Analysis of the pre intervention EMG data showed that, for all stroke participants, timing and amplitude of peak EMG activity in biceps and triceps during all tasks differed from the mean of neurologically intact participants (n=8) ($p<0.05$), using data recorded under the same conditions. Analysis of pre intervention and post session18 EMG data, showed statistically significant ($p<0.05$) changes (mean of all tracking tasks) in timing and amplitude of biceps and timing of triceps EMG towards those of neurologically intact participants. Changes in tracking performance showed a statistically significant ($p<0.03$) reduction in error of the 9 tasks. An association between improved tracking performance and changes in timing and amplitude of EMG was identified. A statistically significant interaction (ANOVA) between tracking and timing of biceps ($p=0.03$) and tracking and amplitude of triceps ($p=0.04$) was detected but not between amplitude of biceps or timing of triceps (i.e. the variables that showed the greatest change towards normal).

CONCLUSION: Five people with upper limb post-stroke hemiplegic underwent 18 training sessions in a planar arm robot in which ES of triceps, mediated by ILC, was used to correct tracking error. An improvement in motor performance and changes in EMG activity in biceps and triceps were observed. An interaction was found between improvement in tracking and some but not all EMG variables.

CHANGE OF THE MUSCLE THICKNESS AND THE MUSCLE FATIGUE OF THE SCAPULA MUSCLES

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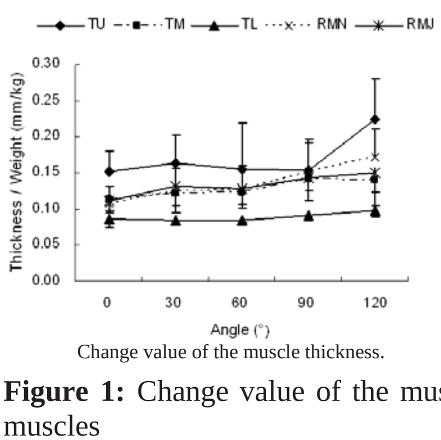
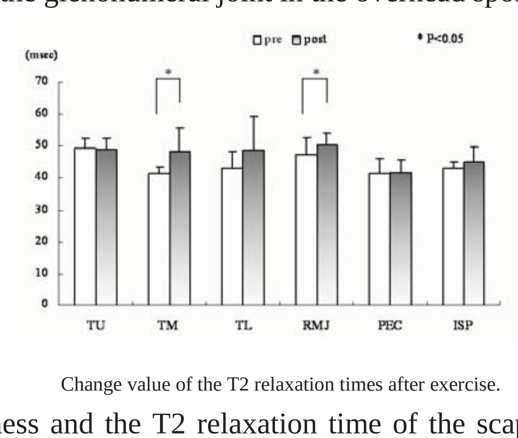
AIM: Scapula muscles contribute to the multidirectional activity of upper extremity and the stability of shoulder complex. Coordination between shoulder joint and scapula, called as Scapulohumeral rhythm allow the six directional of freedom. Too much stress by fast shoulder rotation to make the shoulder disorder. So the functional of scapula is so important for prevention of injuries. The objects were to measure and evaluate quantitatively using ultrasonographic apparatus and MRI the changes of scapula muscles at different shoulder positions.
METHODS: Six experienced male intercollegiate tennis player without shoulder problems volunteered to participate (ago=20.6±1.7yrs, height=172.3±4.2cm, mass=69.4±6.4kg mean±SD). In the scapula plane, I measured form change of scapular muscles (trapezius muscle upper: TU, trapezius muscle middle: TM, trapezius muscle lower: TL, rhomboid muscle, rhomboid muscle minor: RMN) and the serratus anterior muscle using ultrasonic tomography at shoulder abduction. Another method, Before and after performing shoulder internal rotation exercise of 30 deg / sec in 90 degree-abduction in Biodex, MRI was taken and T2 relaxation time of the rotator cuff (infraspinatus muscles: ISP) and scapular muscles (TU, TM, TL, RMJ, pectoralis major: PEC) were calculated.
RESULTS: The muscle thickness value changed in TU and TL, especially TL revealed a change in higher than 90 degrees shoulder abduction. The pectoralis major, trapezius, rhomboid, infraspinatus muscles revealed elevation of T2 value and extension for T2 relaxation time after the exercises by MRI (Figure 1).
CONCLUSION: As for the overhead sports, the activity in more than 45 degrees shoulder abduction is important and scapular muscle functions as a scapular stabilizer at the time of repeated shoulder rotation. Also, it was suggested as for the rhomboid muscle that I respond as scapular stabilizer at the time of shoulder rotation. It was suggested that the shoulder rotation in abduction is influenced by muscle activity of the scapular muscles and dysfunction of scapular muscles was caused by disorder of the glenohumeral joint in the overhead sports.



Change value of the muscle thickness.



Change value of the T2 relaxation times after exercise.

Figure 1: Change value of the muscle thickness and the T2 relaxation time of the scapula muscles

COMPARISSON OF LATISSIMUS DORSI ACTIVITY BETWEEN DOMINANT AND NON DOMINANT ARM IN POLE VAULT BY WAVELET-EMG-ANALYSIS

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AIM: The muscular recruitment of the upper-limbs is a crucial factor in pole vaulting[1] and the M. *latissimus dorsi* (LATD) is mainly activated during brachiation[2]. The goal of this study was to compare the activity of both LATD during a pole vault. The arm connected to the upper handgrip on the pole was considered as dominant.
METHODS: The activity of both LATD of seven experienced pole vaulters (Personal best: 4.85-5.35m) was recorded by surface EMG (Biovision, 2500 Hz, SENIAM). The EMG of each trial was wavelets transformed[3]. Twenty-four vaults were analyzed within four phases between take-off and complete pole straightening (Figure 1). For each phase, the median total intensity and the mean frequency (MNF) were calculated. Inter-phases and inter-limbs comparison were done by a Wilcoxon rank test and a U Mann-Whitney test, respectively.
RESULTS: The intensities and MNFs of the non dominant LATD in phases 2 and 3 were significantly higher ($P<0.05$) than those in phases 1 and 4.The dominant LATD did not show any significant difference among phases in both intensities and MNFs. The dominant LATD had a significant higher intensity than the one of the non dominant side in the phase 4.
CONCLUSION: The arc-shaped intensity pattern of the non dominant LATD is a result of the higher force demand due to the increasing pole bending (Figure 1b) and to the take-off leg swing. Therefore, the higher frequency components of the non dominant LATD become actives. The dominant LATD has an almost constant distribution of active frequency components over the four phases (Figure 1a). In the phase 4, the pole vaulter needs a higher activity of the dominant LATD than the non dominant to complete the humeral extension and keep the reversal position close to the longitudinal axis of the pole.
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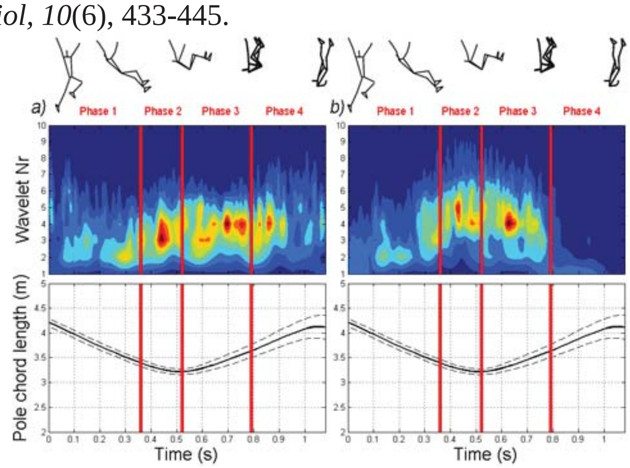

Figure 1: Pole chord length and averaged intensity pattern of the LATD a) of the dominant side and b) of the non dominant side.

LINEAR DISCRIMINANT ANALYSIS APPLIED TO THE INVESTIGATION OF AGE-RELATED CHANGES IN PHYSIOLOGICAL KINETIC TREMOR

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AIM: Tremor is an involuntary, rhythmic, oscillatory movement of a body part that can be classified in many ways, depending on its aetiology, phenomenology, frequency and location. Most investigations on tremor attempt to understand its relation to neuromuscular dysfunctions. Therefore, there is a lack of studies that aim to investigate the complex relation between the physiological tremor and ageing, especially in kinetic conditions. In this context, the main motivation of this research was to quantify age-related changes in the kinetic tremor of clinically healthy individuals.
METHODS: To quantify age-related changes in the kinetic tremor, a number of features extracted from tremor activity, obtained from digitized drawings of Archimedes' spirals, were analysed. In total, 59 subjects participated in the experiments and were asked to draw the spiral with their dominant hand and at their natural speed. These individuals were divided into seven groups according to their ages, being: G1={20 to 29 years}(N=10 subjects), G2={30 to 39 years}(N=10 subjects), G3={40 to 49 years}(N=9 subjects), G4={50 to 59 years}(N=8 subjects), G5={60 to 69 years}(N=10 subjects), G6={70 to 79 years}(N=8 subjects) and G7={80 to 89 years}(N=4 subjects). Two types of analysis were carried out. First, the tremor activity of young (formed by groups G1 and G2) and elderly adults (formed by groups G6 and G7) was investigated by means of traditional features commonly used in tremor analysis. Secondly, Linear Discriminant Analysis (LDA) was employed for the study of the correlation between age and tremor considering the entire group of subjects (from G1 to G7) in order to verify smoother changes that may happen over the ageing. The analyses followed, for each data sample, a sequence of steps, being: linearization of the spiral of Archimedes, estimate of the tremor activity and feature extraction from the tremor activity.
RESULTS: In the first analysis some features yielded significant differences between the groups resulting in a value of p less than 0.05. Regarding to the second analysis, even though some extracted features from the tremor activity yielded a significant correlation with age, we applied LDA for the estimate of the LDA-value aiming to investigate a possible linear correlation between this feature and age. A linear fit was obtained through the relation between age and the LDA-value. An inspection of the parameters of the linear model showed that there is a linear trend between the LDA-value and age. When estimating the correlation between these two variables, we obtained Pearson's correlation coefficient equal to 0.85, indicating a high degree of correlation between these variables. The ANOVA statistical test was applied to the LDA-value data showing statistical significance for most groups.
CONCLUSION: The results showed significant statistical differences between the kinetic tremor activity of the young and elderly groups. Furthermore, it was found that LDA allowed for the estimate of a unique feature so-called LDA-value, which showed to be linearly correlated with age. In this way, this index may have great importance in future researches, in particular in those related to the discrimination between physiological and pathological tremor.
ACKNOWLEDGEMENT: The authors would like to thank the Brazilian government for supporting this study (Project PPSUS/FAPEMIG 2006 Nr. 3300/06).

LIMITATIONS OF ROBOT-GUIDED MOTOR LEARNING

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AIM: The HUMOUR project (Human behavioral modeling for enhancing learning by optimizing human-robot interaction) investigates and develops efficient robot strategies to facilitate the acquisition of novel motor skills and the re-acquisition of motor skills lost as a consequence of stroke or other incidents. The present study focuses on the acquisition of novel skills.

METHODS: We chose a pointing task with a visuo-motor transformation in effect which the subjects had to learn under three different guidance conditions: (a) no guidance (control condition), (b) target guidance, i.e., the manipulandum (PHANToM™ haptic interface) is attracted towards the target position, and (c) path guidance, i.e., the manipulandum is attracted towards the straight line linking start and target position. All subjects were healthy young adults. Their task was to move a cursor to one of 8 different, concentrically arranged targets. Without transformation, hand and cursor would move into the same direction, whereas with visuo-motor transformation the direction of cursor motion was rotated by 75° relative to the direction of hand movement.

RESULTS: During the practice period performance measures, such as movement curvature, revealed a clear advantage for target guidance. In both conditions without guidance and with path guidance movement curvature and initial direction errors were larger and movement time was longer. After the practice period subjects had to perform open-loop test trials (i.e. the cursor was invisible) without visuo-motor transformation. After-effects revealed under this condition are considered to represent successful adaptation to the novel visuo-motor transformation. For both initial and final direction errors the after-effect was largest for the no-guidance condition, followed by the path-guidance and finally the target-guidance conditions.

CONCLUSION: The present findings reveal a beneficial effect of target guidance on performance, but also a negative effect on motor learning of both guidance conditions. Active movement and error feedback are two key aspects of motor learning. The detrimental effect of target guidance can be traced back to the near absence of both of these factors. However, this not true for path guidance which requires active pointing movements and leads to even larger errors during learning than no guidance without showing any benefit for motor learning. The limitations of robot-guided motor learning, that we show, need to be overcome by enhanced guidance algorithms which facilitate both performance and learning, so that skill (re-)acquisition becomes safe as well as rapid and motivating. Fading guidance during acquisition is one type of enhancement which we shall explore next, but there is also the possibility that limitations might be related to the type of learning problem.

JOINT FORCES, MOMENTS AND MUSCULAR ACTIVATION IN HEALTHY AND PATHOLOGICAL UPPER EXTREMITY MOVEMENTS

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AIM: Generally human movement is initialized by muscular activation in which the muscles induce a net moment resulting in a rotation around the anatomical axes of the involved joints. On the other hand, external forces (e.g. gravity) cause joint moments too, which have to be compensated by the muscles when controlled movements are to be achieved. In pathological cases the muscular coordination pattern is often disturbed resulting in unphysiological joint moments and incorrect movement patterns. Since the extremities are joint chains, these effects are not only restricted to the joint the muscle acts on. Moreover all joints of the ipsilateral side and sometimes even of the contra-lateral side are affected. For this reason in clinical gait analysis 3-dimensional kinematic and kinetic data are commonly measured parallel with surface EMG data. In contrast for upper extremity movement, which are more complex than gait, a procedure for kinetic analysis of unconstrained movements has still not been standardized. However, this is an indispensable prerequisite for understanding the muscular co-ordination pattern as well as the resulting movement.

METHOD: For calculation of net joint forces and torques via inverse dynamics, the assessment of kinematic data, external forces and anthropometric parameters is necessary. Joint angles for hand, elbow and shoulder were calculated using a rigid body model for the upper extremities. In order to predefine the movement and increase the reproducibility, a 7-DoF robot-arm presented a predefined 3D path defining a movement which a subject should perform. External forces and torques were measured using a 6-DoF force sensor attached at the robot's endeffector. To detect the muscular coordination, conventional surface EMG was used. The electrodes are placed on the brachioradialis, biceps brachii, deltoideus and trapezius according to the SENIAM recommendations.

Figure 1: Isokinetik 3D Tracking for kinetic analysis of upper extremity

RESULTS: Figure 2 compares shoulder joint forces and moments acting during a shoulder flexion extension task of a healthy subject with those of a patient suffering from an internal shoulder rotation. The pathological internal rotation of the shoulder causes not only an additional force acting along the flexion/extension axis, but also an abnormal high torque around the shoulder abduction/adduction axis. While the abnormal force situation leads to pathological joint loads with consequences for the mechanical strain of the joint, the higher adduction moment has to be compensated by a higher continuous muscular activation of the deltoideus muscle, which is reflected in the muscular co-ordination pattern.

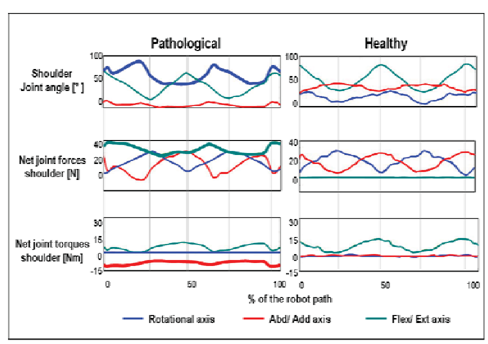

Figure 2: Example of pathology in joint forces and torques compared to a healthy subject.

A METHOD TO ASSESS DURATION OF SUSTAINED MUSCLE ACTIVITY

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AIM: Forest machine operators (FMO) are during harvesting procedures exposed to fixed and/or non-neutral body postures while attending the electronic timber production for long working days. The aim of this study was to develop a data reduction method that measures the amount of periods of different length with Sustained Low-level Muscle Activity (SULMA) and to relate these temporal measures to self-reported neck pain.

METHODS: sEMG of the right upper trapezius muscle ('right neck') of FMO driving either harvesters (n=19) or forwarders (20) and researchers within forestry (20) was measured during one working day. The myoelectrical activity was acquired by a logger (Physiometer, PH400). A 'SULMA period' was defined as a period of muscle activity continuously above 0.5% EMG_{max} for 1.6 s. or longer. The number of SULMA periods was registered for predetermined intervals of duration (1.6-5s, 5-10s,…, 10-20 min, >20 min). Pain in the right part of the neck was assessed by Borg' CR 10 scale as a point estimate at baseline and at follow-up by the Standardized Nordic Questionnaire where the scale was dichotomized into the categories ≤30 and >30 days of pain during the previous year. A logistic regression model was used to find the odds ratio (OR) for pain >30 days as a function of EMG variables and confounding factors.

RESULTS: The method distinguished between the occupational groups, with harvesters having the highest number of long SULMA periods. A significant positive correlation was found at baseline between the numbers/hour of SULMA periods > 10 min duration and neck pain (figure 1A) (1). A SULMA period per hour > 8 min duration at baseline resulted in an OR of 3 for neck pain > 30 days one year later (figure 1B) (2).

CONCLUSION: The method could be used in work load assessment in search of muscle activity pattern that may increase the risk for muscle pain. The method is used in an ongoing biofeedback project aimed to reduce long SULMA periods in the work pattern.

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2 Østensvik T, Veiersted K.B, Nilsen P. Association between numbers of long periods with sustained low-level trapezius muscle activity and neck pain. Ergonomics. 2009; 52:12: 1556-1567.

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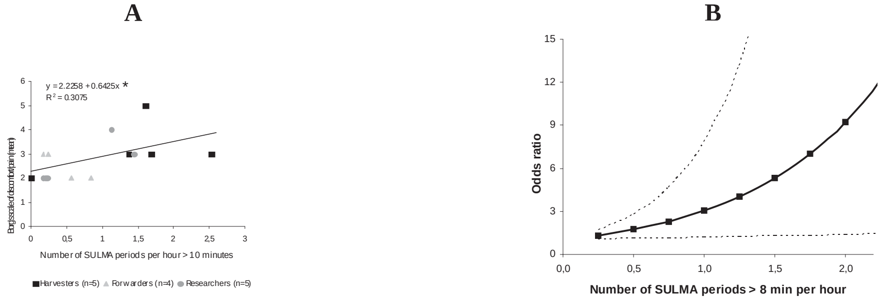

Figure 1: A. At baseline: Borg's CR 10 scale > 0.5 (more than 'very little pain') in the neck and numbers/hour of SULMA periods > 10 min duration in the right neck during one working day in the three male occupational groups (n=13). **B. After one year**: OR of neck pain > 30 d last year compared to ≤ 30 d as a function of the number of SULMA periods > 8 min/hour at baseline. The 95% CI (broken line) are also shown (n=45). Logistic regression equation: $p = e^{(-2.448 + 1.112 * SULMA > 8 min)}$

MYOELECTRIC SIGNAL FEATURE PERFORMANCE IN CLASSIFYING MOTION CLASSES IN TRANSRADIAL AMPUTEES

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AIM: We investigated the performance of different features of surface myoelectric signals (MES) from the residual arm muscles of transradial amputees in predicting the classes of intended movements, which was conducted on able-bodied subjects in most previous studies.
METHODS: Five amputees with unilateral transradial amputation participated in the study. EMG signals were recorded by 12 bipolar electrodes. Three feature sets, six order auto-regression model coefficients, four conventional time-domain (TD) parameters (mean absolute value (MAV), zero crossing (ZC), waveform length (WL), and slope sign change (SSC)) and revamped TD feature group (root mean square (RMS), Willison Amplitude (WAMP), ZC, and MAV), were extracted from EMG signals. The performances of these feature sets in identifying motion classes were evaluated over two types of EMG pattern classifiers, linear discriminant analysis (LDA) and Gaussian mixture model (GMM). Eleven voluntary arm and hand movements were chosen in the study.
RESULTS: From Figure 1, it can be clearly seen that using a LDA classifier, the revamped TD feature set outperformed the conventional TD feature set and AR coefficients in classifying the motion classes. When classified by the GMM, the difference among these three feature sets was not significant ($p>0.05$). However, it was evident that the combination of the AR set and the revamped TD set exhibited the highest classification accuracy in comparison with other feature sets. Our results show that the combination outweighed the TD conventional set by an average over 5% either on the GMM ($p= 0.0051$) or LDA ($p= 0.0377$).
CONCLUSION: The classification performance for the 11 different arm and hand movements in transradial amputees remained at the relatively low level due to physiological limitations of residual musculature articulations. The combination of the AR and revamped TD set showed the best performance with a classification accuracy of 72% on the GMM and 81% on the LDA. This suggested the good promise and feasibility of this combined feature set.
ACKNOWLEDGEMENT: We would like to thank the Neural Engineering Center for Artificial Limbs of the Rehabilitation Institute of Chicago, for providing the raw EMG data for this study. This work was supported by the National Natural Science Foundation of China (General Program) #6097111076 and Shenzhen Basic Research Grant #JC200903160393A.

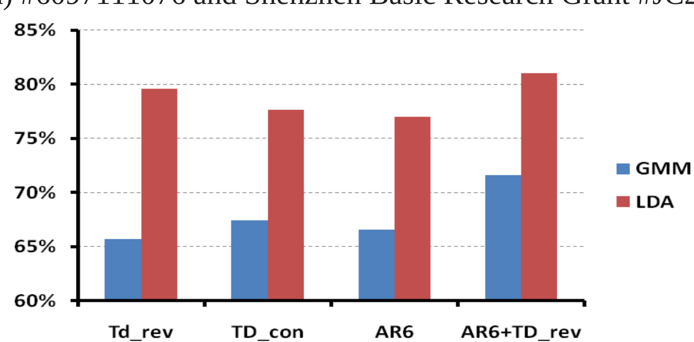

Figure 1: Classification performance on transradial amputees, averaged across five subjects

EFFECT OF MUSCLE LENGTH ON MECHANOMYOGRAPHIC ACTIVITIES DURING SINGLE TWITCH CONTRACTION OF QUADRICEPS FEMORIS MUSCLES

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AIM: The mechanomyogram (MMG) has been considered to be originated from pressure waves due to lateral expansion of contracting muscle fibers and to reflect mechanical activities of muscle fibers. However, detailed relationship between muscle length and MMG signal has not been clarified. The purpose of the present study was to investigate the effect of muscle length on the MMG signal during single twitch contraction elicited by electric stimulation.

METHODS: Fifteen healthy male adults participated in this study after providing their informed consent. Single twitch isometric contraction of quadriceps femoris muscles was elicited with percutaneous femoral nerve stimulation. In addition, the motor point of rectus femoris muscle was stimulated to produce selective twitch contraction of the muscle. The muscle length was determined using different combinations of hip and knee joint angle. The MMGs were recorded by small accelerometer on individual muscle bellies of three muscle heads; rectus femoris, vastus lateralis and vastus medialis muscle. The electromyograms (EMGs) of same muscles were simultaneously recorded with bipolar surface electrodes placed at both sides of the accelerometer. The evoked twitch force was measured as knee extension force with dynamometer.

RESULTS: The EMG showed similar amplitude over the range of muscle length determined by combinations of hip and knee joint angle. When whole quadriceps femoris muscles were stimulated by femoral nerve stimulation, the MMGs recorded from individual muscle bellies were greater at shortened muscle length because of the slack of muscle-tendon complex. When rectus femoris muscle was selectively activated, the MMG demonstrated the greatest amplitude at the intermediate length whereas it decreased with muscle shortening as well as lengthening.

CONCLUSION: The behavior in the MMG associated with muscle length was consistent with that in force production. The present results suggest that the MMG reflects interaction between actin and myosin filaments of skeletal muscle fibers affected by muscle length.

FREQUENCY DEPENDENT MOTOR UNIT CONDUCTION VELOCITY: A COMPARISON OF COHERENCE AND WAVELET ANALYSIS.

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AIM: The abductor pollicis brevis (APB) muscle revealed the decay of the mean frequency of the EMG signal and of the average conduction velocity (CV) of the motor units with fatigue (Barandun et al., J Electromyogr Kinesiol. 2009). Supposedly fast conducting motor units contribute higher frequencies to the power spectrum of an EMG signal. Thus CV measured at higher frequencies should be larger than those measured at low frequencies. The purpose of this study was to compare the CV as a function of frequency a) using classical coherence analysis and b) using wavelet analysis.

METHODS: EMGs were sampled from the APB muscle from hands of 12 subjects by three electrodes placed between the innervation zone and the tendon. Two bipolar recordings were measured at maximum voluntary isometric contraction. The delay between the signals was computed by a coherence analysis (Rosenberg et al., Prog. Biophys. molec. Biol. 1989). During wavelet analysis the delay was found shifting the real parts until they correlated maximally. CV was computed dividing the inter-electrode distance by the measured delays.

RESULTS: The coherence (Figure (a)) was above 0.7 in a range from about 30 Hz to 250 Hz. The CV-spectrum (Figure (b)) obtained by the coherence analysis had a higher frequency resolution while the one obtained by the wavelet analysis had a smaller variance. Both analysis methods revealed that the CV was high at low frequencies, went through a minimum at about 170 Hz and increased slightly at higher frequencies.

DISCUSION: Both methods yielded the same frequency dependency of the CV. The expected increase of CV with frequency was observed at frequencies above 170 Hz. However, there is no satisfactory explanation for the observed increase of CV with decreasing frequency below 170 Hz. The most common explanation, that there is a non conducting signal contained in the EMG, implies that the signal must be different at each electrode otherwise it would be rejected by the bipolar recording and it must be coherent. The second possibility would be that there are large motor units with a wide but fast traveling action potential. For now, we can only speculate about the reasons behind this observation. The reasons have to be debated. However, the present result indicates that the CV-spectrum is independent of the method of analysis.

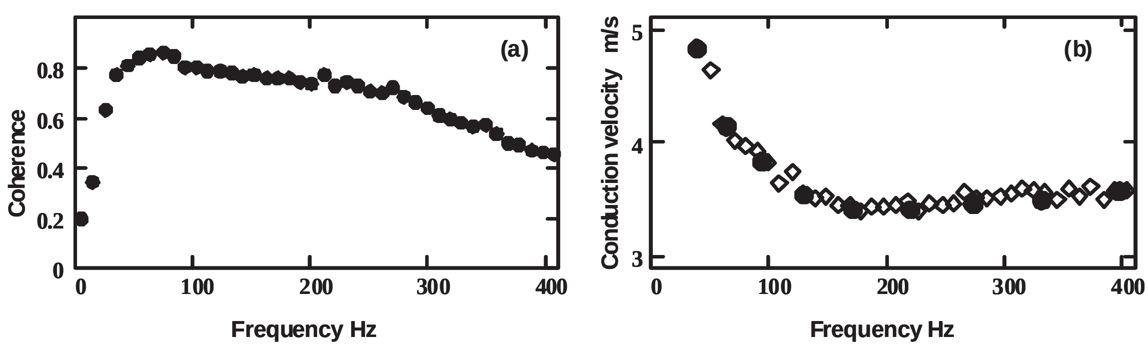

Figure 1: (a) Average coherence-spectrum for all hands. (b) CV-spectra obtained by coherence analysis (diamonds) and by the wavelet analysis (dots)

SURFACE ELECTROGRAPHY(SEMG) TOPOGRAPHY FOR LOW BACK PAIN ASSESSMENT

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AIM: In previous studies, muscle function impairment was found to be low back pain (LBP)-associated. Surface electromyography (SEMG) provides an objective measurement of the trunk muscle function which may serve as a useful tool in LBP diagnosis and monitoring of rehabilitation progress. This study aims to assess the feasibility of SEMG as a reliable and objective tool for differentiation of normal and LBP patients, and monitoring of rehabilitation progress.
METHODS: One hundreds healthy subjects were recruited to establish the normal pattern of lumbar muscle activity. An array of surface EMG electrodes was applied to the low back area and recorded during forward bending. The root mean square (RMS) of the sEMG signals were calculated as a function of both position and time to produce streaming topographical videos of the muscle activity in the lumbar region. In addition, a clinical study was carried out with 54 LBP patients.
RESULTS: Figure 1(a) showed the streaming topography of normal during forward bending. The lumbar muscle contraction synergy was found to be symmetric. In phase 1 and phase 2, high intensity EMG was seen in lumbar 5 level. In phase 3, the contraction was found gradually raising to lumbar 4 and then lumbar-3 level. In contrary, LBP patients, more or less, showed abnormal pattern in streaming topography. Figure 1(b) showed a slightly abnormal pattern of a patient, where the high contraction EMG signal appeared in higher lumbar level during phase 1 and 2 of forward bending.
CONCLUSION: In this study, electrode-array was designed to cover the low back region. To visualize the EMG activity, topography of RMS distribution was plotted to interpret the co-ordination of muscles. In summary, sEMG topography provides a dynamic analysis of lumbar muscle activities and illustrates the synergy of muscle contractions, which may be useful to improve physiotherapy management of LBP.
ACKNOWLEDGEMENT: This study is supported by SK Yee Medical Foundation Grant (203210/207210) and RGC grants (GRF 712408E).

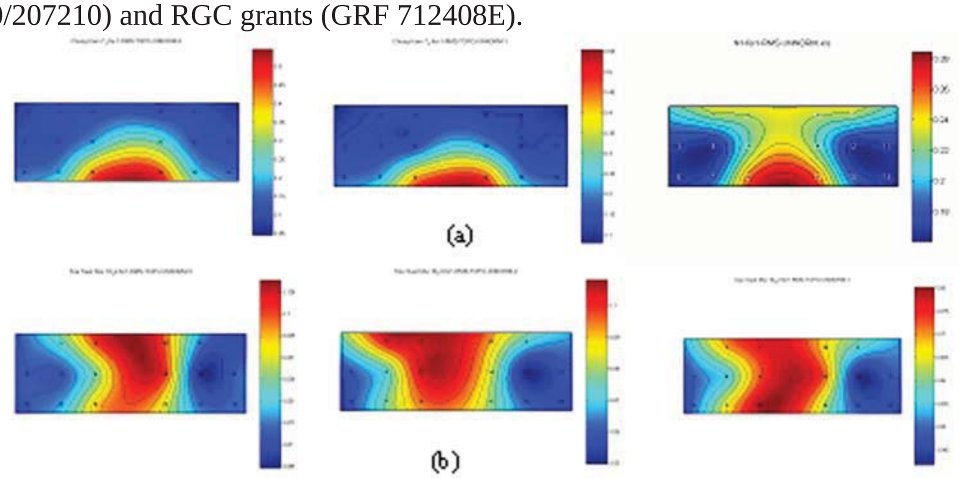

Figure 1: Typical streaming topography from phase 1 to 3 of forward bending in (a) Normal and (b) LBP. .

EXAMINATION OF LONG TERM MOTOR UNITS ACTIVITY WITH THE MULTI-CHANNEL SURFACE ELECTRODES

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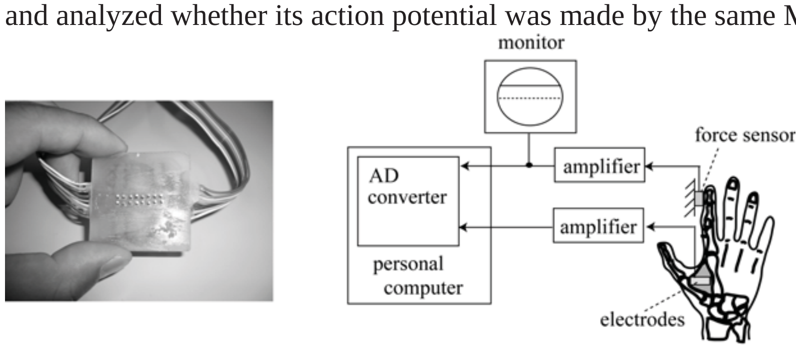
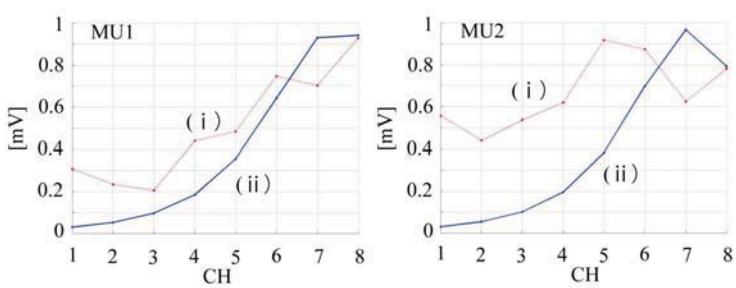
AIM: In this paper, we had considered whether we could examine long term motor units (MUs) activity with the signal analysis of the multi-channel surface electromyogram (EMG).
METHODS: EMG were obtained with eight-channel bipolar surface electrode array (Figure 1(a)). The electrode array was consisted of sixteen stainless electrodes of 1 mm diameter. The electrodes were placed in a position over the first dorsal interosseous muscle (FDI). A subject was instructed to put his hand on the desk horizontally where the thumb and the fingers were loosely fixed except the index finger. The isometric adductor torque of the index finger was measured. Both the isometric force and EMGs were A/D converted at the 10 kHz sampling frequency, and stored in a PC (Figure 1(b)). The electrode was placed at the same position, and EMG was recorded at different day. The territories of the MUs were analyzed with our proposed simulation methods which comparing the each channel action potential of EMG, and analyzed whether its action potential was made by the same MU.



(a) (b)

Figure 1: (a) Eight-channel bipolar surface electrode, (b) Experimental set up.
RESULTS: Figure 2 shows the experimental results. EMG of (a) and (b) were recorded at the different day. In this figure, (i) was the measured line, (ii) was the simulated line using our proposed method. In both (a) and (b) of simulation results, longitudinal width of MUs territory was 2.0 mm, horizontal width was 2.0 mm. Though, MUs depth from the surface was slightly different. MU1 was 4.5 mm. and MU2 was 4.0 mm.



(a) (b)

CONCLUSION: Simulation results were almost similar, and we had considered the possibility of examination of the same MUs activity during a long time.

A NOVEL APPROACH FOR MEASURING LOWER-LIMB MUSCLE SPECIFICITY DURING WEIGHT BEARING

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AIM: We present a new method for evaluating neuromuscular control of the muscles about the knee joint during a highly controlled quasi-isometric closed kinetic chain task. The protocol is based on the muscle-specificity studies of Lloyd and Buchanan[1]. Subjects were required to generate varus-valgus and antero-posterior loads at the knee and the muscle activation and joint loading were examined to identify the strategies that the nervous system uses to generate these loads as a response to a biofeedback-driven target matching task. This task requires subjects to control an onscreen cursor by modulating ground reaction forces with their support limb.
METHODS: Subjects stand with one foot in a boot fixed to a multi-axis force platform while the other foot rests on a second force platform. The subjects must then position a circular cursor and needle over a target (figure 1): cursor movement occurs in response to loads that the subjects produce against the force plate requiring in the antero-posterior and medio-lateral directions (causing target displacement), internal-external rotation (needle position) and %-weight-bearing (target size). Visual feedback of these applied forces is given to the subjects via the moving cursor and needle, not unlike controlling a computer mouse. A successful target match is followed by 30 seconds of rest. A new randomly selected target position then appears and the task is repeated. Eighteen targets positions are evenly distributed in 20° intervals about the subject perpendicular to the tibial axis. To achieve the target, subjects must apply a force equal to 30% of the force generated during maximal calibration trials.
Surface EMG of the rectus femoris, vastus medialis, vastus lateralis, semitendinosus, biceps femoris, medial gastrconemius, lateral gastrocnemius and tensor fascia lata were collected (Delsys), along with 3D limb position (Vicon) and ground reaction forces (Bertec) during the 3 seconds prior to, and 1 second during, a successful target match. The specificity of muscle activation was determined by expressing MVIC-normalized EMG in polar coordinates as a function of the directions of the resultant ground reaction forces for each target position.
RESULTS: We are currently evaluating gender-related differences in muscle control strategies. Preliminary results indicate that unlike the calibration trials when subjects produce maximal directed loads, the subjects illicit high levels of muscular co-activation during relatively low-loading in order to achieve the assigned targets.
CONCLUSION: This approach is an effective means of investigating fine motor control of the lower limb during weight-bearing tasks.
ACKNOWLEDGEMENT: The authors would like to acknowledge Prof. TS Buchanan for sharing his knowledge with respect to the development of this protocol.

References: [1]Lloyd DG, Buchanan TS. (2001) Strategies of muscular support of varus and valgus isometric loads at the human knee. J Biomech. 2001 Oct;34(10):1257-67

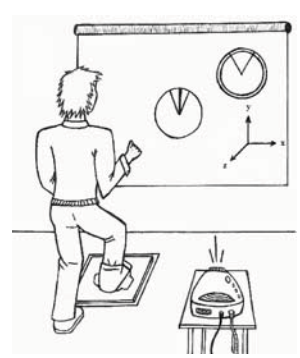

Figure 1: Setup for muscle specificity testing illustrating subject position; The subject must move the cursor (circle in centre) to the target (circle to right) by applying loads to the force platform. These loads affect the size, orientation and direction of the cursor and must be controlled for a successful target match.

BICEPS RECOVERY AND REACH-TO-GRASP CONTROL AFTER BRACHIAL PLEXUS INJURY

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AIM: The aim of this study was to examine the time course of biceps recovery and development of reach-to-grasp control in 3 to 6 mo infants who sustained brachial plexus injury. Neonatal brachial plexus injury (BPI) is often caused by excess traction to the brachial plexus (C5–T1) during birth and can lead to weakness and sensory impairments. The association between impairments and delayed or maladaptive reach-to-grasp skills has not been determined rigorously.
METHODS: Ten infants, 3 to 6 mo; five with BPI and five age-matched, typically developing controls performed a reach-to-grasp task to a vertical toy at 50% arm's length. Kinematic analysis (Polhemus Liberty; Colchester, VT; 120 Hz) was used to examine fifteen, 15 s reaches (five each arm, five bimanual). Surface electromyography recorded biceps activity (MyoPAC system-RUN Technologies, Laguna Hills, CA; 1000 Hz). Videotape was used to determine whether palm contact with the toy was made via supination. The Active Movement Scale (AMS) measured active arm motion.
RESULTS: Mean AMS scores gradually improved for infants with BPI ($p<0.05$). During reaching with the involved arm, elbow flexion, forearm supination and the number of palm contacts to the toy increased by 6 mo (all, $p<0.05$). By 6 mo, peak hand velocity increased ($p<0.05$) and the hand path ratio decreased ($p<0.05$). Movement time decreased ($p<0.05$) and biceps on-time decreased in the involved arm by 6 mo ($p<0.05$) suggesting biceps activity was more phasic as seen with the non-involved arm and both arms of control subjects.
CONCLUSION: Improved AMS scores and reach to grasp control seemed to coincide with biceps recovery in infants with BPI. Yet, at 6 mo maladaptive patterns persisted perhaps due to residual muscle imbalances, glenohumeral joint changes and habitual practice patterns. As mechanisms of neural recovery and secondary impairments are better understood more effective strategies may be developed to hasten recovery and promote prehensile skill.

SOURCE LOCALIZATION IN SURFACE ELECTROMYOGRAPHY

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AIM: The aim of this project is to provide a detailed mapping of the activity of individual muscles by processing surface electromyography (sEMG) data from a surface grid of recording sites in order to retrieve their origins in the muscles. This will provide information about muscle function that is not currently accessible by any means. We call the resulting system CMG, for Computed Myography.

METHODS: Our source localization methodology consists of the following steps, illustrated in the figure. 1) Acquire a three dimensional geometry model by the segmentation of MRI data. 2) Build a finite element model (FEM) simulator (a forward model) for 3D volume conduction which can predict surface voltages (e.g., data) from given current sources. 3) Using an inverse model, compute the most likely current sources that can explain measured data by minimizing the least square error of predicted versus measured data plus a regularization function which incorporates a priori information on the solution. The a priori information includes the location of muscles, orientation of muscle fibers (necessary to obtain the muscle conductivity anisotropy directions), and spatial smoothness (i.e., correlation between nearby sources) of the source in the muscles.

RESULTS: We have obtained a model of the upper arm and have performed experiments with real and synthetic data. Results with synthetic data suggest the overall activation of muscles can be obtained to with an accuracy of about 10% with 21 sEMG sensors. Results with human data look promising but have not been validated yet. An illustrative reconstruction is depicted below.

ACKNOWLEDGEMENT: This work was supported in part by the Peter Wall Institute for Advanced Studies, Canada Research Chairs Program, NSERC, CFI, and BC KDF.

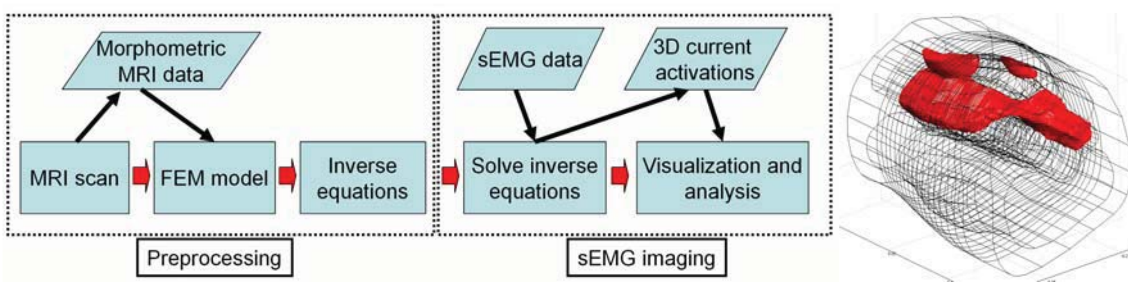

Figure 1: Systems diagram of the CMG system and an illustrative reconstruction.

ACTIONS OF LEG MUSCLES IN STANDARDIZED VERTICAL JUMPS WITH AND WITHOUT STRETCH-SHORTENING CYCLE EXPRESSED THROUGH EMG, KINEMATIC AND DYNAMIC SIGNAL

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AIM: The estimation of internal forces and characteristics of human locomotion may lead to progresses in prevention or treatment of clinical cases, exercise and sport performance as well as in the project of training and rehabilitation equipment. Despite the efforts for the determination of 'in vivo' forces in synovial joints and at muscular level, there is no established methodology for direct measurement of internal forces during execution of normal human movement. Selected approach is based on inverse dynamic analysis, integrating data from ground reaction forces with kinematic displacements, anthropometric and electromyography data in order to achieve some insight into neuromuscular system revealed during human locomotion. Stretch-Shortening Cycle (SSC) is responsible for leg muscles forces that contribute together, with joint forces and moments, for the internal actions in association with external forces of gravity and ground reaction forces, for the biokinematic performance revealed in the present approach through vertical jump.
METHODS: Based on the effects of human movement expressed through kinematics, the external actions of gravity and ground reaction forces measured with force platform we conducted an inverse dynamic analysis for each subject, using multi-body dynamics according to anthropometric data of the subjects, kinematic and dynamic data of movement, to obtain the resultant of the forces acting across each joint as the causes of movement and related it with electromyography signal of main propelling muscles, acquired simultaneously during vertical jump.
RESULTS: The tests included 6 subjects executing 3 trials of each kind of considered jump, counter movement (CMJ), drop (DJ) and squat (SJ) jump, respectively with short, long and without SSC. Anthropometric data were measured and ground reaction forces and torques acquired with force platform (AMTI BP2416) at 1000 Hz. Kinematic data of 3D positions of markers located at main joints according to Dempster Model (1990) were captured by a pair of cameras JVC9800 operating at 100 Hz rate, and EMG collected with a 32 channels Biotell 99 system operating at 2000 Hz frequency. Force platform data was sub sampled to 100 Hz, displacement signals were filtered by a second-order low-pass Butterworth filter with an optimized cutoff frequency and electromyography data was rectified and integrated to reflect muscle activity of rectus femoris, vastus medialis, vastus lateralis, superior gemellus and inferior gemellus. Mass segments and moments of inertia were calculated from anthropometric segment parameters. Filtered kinematic data were numerical differentiated through finite differences to obtain segment velocity and acceleration. Ground reaction forces and torques obtained from the force platform during contact were inserted into movement equations of contact feet according to its mass and moment of inertia and the equation was solved according to its acceleration to obtain forces and moments at proximal joint of feet, and the process propagates in each instant to calf and thigh to obtain resultant forces an moments in each joint during time of jump.
CONCLUSION: The obtained joint actions agree with acquired EMG activity of each segment muscles for $p<0.05$ in eccentric and concentric phases for CMJ, DJ an SJ.

EFFECT OF POSTURE AND EXERCISES PERFORMED WITH AN OSCILLATORY POLE IN THE TRUNK MUSCLES EMG ACTIVITY

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AIM: To analyze the electromyographic (EMG) signal ratios between the front over back trunk muscles (F/B = rectus abdominis + internal oblique + external oblique / multifidus + iliocostalis lumbar), multifidus over iliocostalis lumbar (MU/IL) and internal oblique over external oblique (IO/EO), during different exercises performed with an oscillatory pole (Flexibar®) in standing and sitting posture.
METHODS: Twelve healthy females performed three different exercises with a oscillatory pole at standing and sitting postures in a single session (exercise I: approximately 90º shoulder flexion and pole parallel to the floor, exercise II: approximately 180º shoulder flexion and pole parallel to the floor, and exercise III: approximately 90º right shoulder flexion and pole perpendicular to the floor). All exercises were performed for 15 seconds with a rest period of 60 seconds, and the rhythm of movement was controlled by a metronome set at 5 Hz (300 bpm). The neutral posture of pelvis and lumbar spine were adopted in the beginning of the exercises and the participants were instructed to maintain the alignment of the reflective markers located on the shoulder, hip and ankle by means image feedback from digital camera (Panasonic®). EMG activity of the rectus abdominis (RA), IO, EO, MU and IL was continuously measured by a telemetric EMG system (Telemyo 900 – Noraxon®). The RMS (Root Mean Square) values were analyzed by over 250 ms windows with overlap of 125 ms during five seconds of exercise (period between the fifth and the tenth second), and were normalized by mean value. With these values the ratios F/B, MU/IL and IO/EO were calculated. For statistical analysis was used ANOVA for repeated measures and Bonferroni post hoc tests. The level of significance was set at $p < 0.05$.
RESULTS: As showed in Table 1, between the exercises was verified a greater values for the ratios F/B and MU/IL in the exercise I and III in relation to the exercise II, while the IO/EO ratio showed greater value in the exercise III in relation to the exercise I and II. Between the postures, all the ratios presented greater values in the exercises performed in the standing posture in relation to the sitting posture.
CONCLUSION: The different position of oscillatory pole in each exercise contribute to emphasize the specific muscle activity as well in the rations between them, mainly when it was positioned in front of trunk; the same happened in function of posture, being greater in standing posture for the necessity to stabilize the trunk.
ACKNOWLEDGEMENT: FAPESP (2005/02535-2).

Table 1: Mean and standard deviation of the ratios in the exercises and postures.

	Exercises			**Postures**	
Ratios	**I**	**II**	**III**	**Standing**	**Sitting**
F/B	1,50 ± 0,02[a]	1,15 ± 0,01	1,96 ± 0,01[a]	1,69 ± 0,01[c]	1,38 ± 0,01
MU/IL	1,09 ± 0.00[a]	1,00 ± 0,03	1,10 ± 0,00[a]	1,10 ± 0,10[c]	1,00 ± 0,06
IO/EO	1,20 ± 0,010	1,02 ± 0,01	1,10 ± 0,00[a,b]	1.18 ± 0,01[c]	1,09 ± 0,08

[a] p< 0,05 in relation to the exercise II; [b] p< 0,05 in relation to the exercise I; [c] p< 0,05 in relation to the sitting posture.

COMPARISON OF THE ELECTROMYOGRAPHIC FATIGUE INDEX AND THE METABOLIC THRESHOLDS DURING INCREMENTAL RUNNING PROTOCOL

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AIM: To determine and compare the Electromyographic Fatigue Index (EMG_{FI}), anaerobic (AT) and lactate (LT) thresholds in six lower limb muscles during incremental treadmill running protocol.

METHODS: Eleven runners (24.2 ± 6.1years, 70.3 ± 11.7kg, 1.78 ± 0.05m) performed incremental running protocol on treadmill with initial speed of 10 $km.h^{-1}$ and with increments of 1 $km.h^{-1}$ every three minutes up to exhaustion (Vmáx = 17 $km.h^{-1}$±1.3). Between each increments there was 30 s intervals in which 25 µl blood samples were collected for the determination of AT and LT. The EMG data was obtained by Telemyo 900 system (Noraxon USA Inc., Scottsdale, AZ). The EMG_{FI} was determined for rectus femoris (RF), vastus lateralis (VL), vatus medialis (VM), biceps femoris (BF), tibialis anterior (TA) and gastrocnemius lateralis (GL) muscles. For each muscle, the RMS values (Root Mean Square) were calculated every five seconds in the last 120 seconds of each velocity and plotted as a function of time to calculate the slope. Linear regression of these slopes was performed with its respective speeds to determine the EMG_{FI}, which is defined as the y-intercept . The blood lactate was determined by electrochemical method (YSL 2300 STAT, Yellow Springs, Ohio, USA). The LT was calculated by means of the inflexion point in the lactate-intensity curve and the AT was determined by means of linear interpolation (concentration of 3.5 mM). A one-way repeated measures ANOVA was used to determine differences between the $EMG_{FI,}$ AT and LT, and the level of significance was set at $p < 0.05$.

RESULTS: The EMG_{FI} values were similar to AT and across all muscles; however, VL and BF EMG_{FI} and AT had significantly greater values than LT.

CONCLUSION: The EMG_{FI} methodology allowed to estimate the transition from aerobic to anaerobic metabolism during incremental treadmill running protocol, suggesting that this EMG index represents a non-invasive method to evaluate muscular fatigue.

ACKNOWLEDGEMENT: The authors would like to thanks the FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo, 2005/02535-2 and 2007/58339-2) and CAPES (Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior).

Table 1: Mean velocity values (± SD) corresponding to EMG_{FI} (RF, VL, VM, BF, TA and GL), AT and LT.

EMG_{FI} ($km.h^{-1}$)						**AT**	**LT**
RF	**VL**	**VM**	**BF**	**TA**	**GL**	($km.h^{-1}$)	($km.h^{-1}$)
13.5 ± 0.9	13.8* ± 0.9	13.8 ± 1.1	13.9* ± 0.8	13.9 ± 1.1	13.7 ± 0.9	14.9* ± 1.7	12.8 ± 1.0

* $p < 0.05$ in relation to the LT velocity.

ADVERSE SHOULDER ADDUCTOR ACTIVATION INDICATES FOR GLENOHUMERAL INSTABILITY IN PATIENTS WITH ROTATOR CUFF TEARS

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AIM: Demonstrate increased deltoid activation in patients with massive rotator cuff injuries to compensating the lost rotator cuff elevation moments and demonstrate the causal but intuitively adverse adductor activation while generating elevation moments.
METHODS: Increased glenohumeral (GH) moment loading with a constant external force is suggested to result in augmented deltoid activation in patients relative to controls. GH-stability will only be affected by deltoid force increase, not by external force because constant, neither by rotator cuff force because absent. GH-stability normalizing adductor muscle activity is assumed to appear.
Deltoid activity increase is provoked by an isometric 'differential' two external downward arm loadings condition with constant forces and increasing moment (arm) (Fig.1) both in an experiment (*rIEMG* in 10 patients, 10 controls) and a musculo-skeletal shoulder model simulation (estimated muscle force F_{muscle}, GH-stability). Adverse adductor activation is demonstrated by the *activation ratio (AR)*, i.e. the relative activation of the muscle in its favorable '*in-phase (IP)*' direction (positive moment) minus the activation in the adverse '*out-of-phase (OP)*' direction (Eq. 1) for teres minor (TMn), teres major (TMj), latissimus dorsi (LD) and pectoralis major (PMj). This requires additional arm loading with equal force magnitude but opposite upward direction. Activation is either *rIEMG* or muscle *force*.

$$AR_{muscle} = (A^{IP}_{muscle} - A^{OP}_{muscle})/(A^{IP}_{muscle} + A^{OP}_{muscle}) \quad , \quad [-1 \le AR_{muscle} \le 1] \qquad \textbf{(1)}$$

where AR_{muscle} = -1 or 1 indicate maximal adverse or 'in phase' activation respectively
RESULTS: Both experiment and model simulation show relative increased deltoid activation in patients with increased downward moment loading, relative to controls (Fig.1). Patient model simulation demonstrated GH-instability and related adverse arm adductor force (Fig.1). The experiment demonstrated similar arm adductor rIEMG (Fig.1).
CONCLUSION: Differential moment loading demonstrates the causal relation between increased deltoid activation and compensatory *ad*ductor muscle activation. Adverse *ad*ductor activation in patients was attributed to glenohumeral instability. The moment loading protocol discerns patients with cuff tears from controls based on rIEMG.

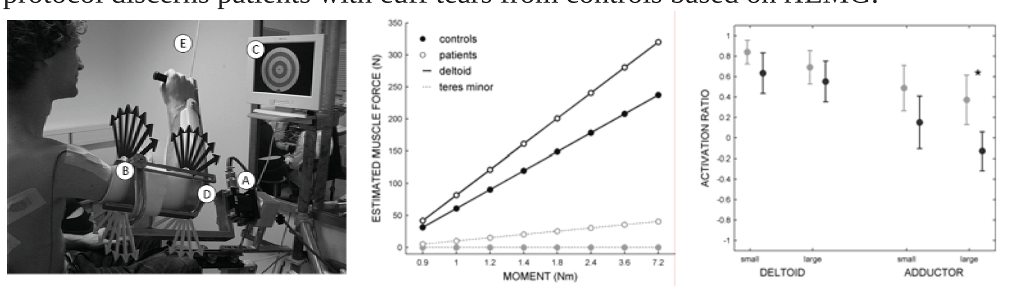

Figure 1: Left: Experimental isometric arm moment loading at fully supported arm (B/E) with constant opposite forces (arrows) at small (B) and large (D) moment arm. Forces perpendicular to upper arm are recorded (A) and visualized (C). Middle panel: Model simulation demonstrates increased deltoid force and adverse adductor activity in patients relative to controls. Right: Significant adverse adductor activity (reduced *AR*) in patients (grey) at *large* moment loading, no adverse deltoid activation.

EFFECT OF LIGHT POSTURAL MOVEMENTS ON SPASTICITY, FINE MOTOR SKILLS, AND ATTENTION OF CHILDREN WITH CEREBRAL PALSY

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AIM: People with Cerebral Palsy (CP) have often difficulties with spatial concepts, spatial learning, and attention, which influence their academic abilities; this is partially due to muscle tone problems and lack of postural control. Clinical experience with CP- children shows that a combination of light movements and the possibility to change sitting-posture reduces the spasticity in the neck and shoulder muscles and makes it possible for the child to sustain its attention for a longer period of time. The goal of this study was therefore to investigate how spasticity, upper-limb fine motor skills, and attention are affected by light postural movements in sitting position.
METHODS: Ten CP-children (one female, nine males; age range: 10.8–16.4 years; mean age 14.5 ± 1.9 years) participated in this study. The light movements were generated by a pillow containing four cells that can be inflated/deflated using a pneumatic system; each cell produced a vertical lift of approximately 5 cm. The experiment consisted of two sessions where the spasticity of the flexor and extensor muscles of the neck was assessed by the Ashworth score, the upper-limb fine motor skills were evaluated using 2 items from the Movement ABC-test: Item 1 (shifting or turning pegs) and Item 3 (flower trail), and attention was tested behaviorally using an attention orienting task in which the cued reaction time (RT) for valid targets was recorded. In one session, the pillow generated light movements (treatment session), while in the other it did not (control session); the order of the sessions was randomized. Assessments in both sessions were performed before and after the CP-children sat for 20 minutes on the pillow. Thus, each subject was evaluated in four experimental conditions: before and after treatment, and before and after control.
RESULTS: There was a tendency towards a reduction of spasticity in the flexors of the neck in the after treatment condition as compared with before treatment (P=0.06). There were no changes in the spasticity level of the flexors in the before and after control conditions, neither changes in the spasticity level of the extensors of the neck in both sessions (control and treatment). The CP-children performed the "shifting or turning pegs" test faster with their preferred hand after treatment than before treatment (P<0.005), while there was a tendency towards a faster execution of the task with the non-preferred hand in the after treatment condition than before treatment (P=0.06). No differences were detected before/after the control condition for both hands. Also, no differences were found before/after the two sessions in the "flower trail" test of the CP-children. RT results show that the CP-children reacted slower in the before control condition than after control (P<0.001), however, generally seen the analysis shows that the before control condition was significantly different from all the other conditions (P<0.001).
CONCLUSION: Light movements during sitting position may have a potential application in daily academic settings and for clinical treatment, in order to improve the ability to perform fine motor skills using the upper-limbs and to reduce spasticity of the flexor muscles of the neck in CP-children.
ACKNOWLEDGEMENT: The authors would like to thank *Den Europæiske Fond for Regionaludvikling, Mayland-Smith A/S,* and *Scaniro A/S* for sponsoring the project.

ASSESSMENT OF BILATERAL FORCE CONTROL OF MASTICATORY MUSCLES BY A REACHING TASK SYSTEM

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AIM: Motor control is an important aspect of mandible function in health and disease. The ability to independently control left and right clenching force has not previously been investigate. A reaching task system aimed to assess and characterize the bilateral control of jaw-closing muscles is presented

METHODS: 13 healthy subjects (7 females, 6 males; age range 24 to 40 yr), participated in this study. The precision of bite force tuning was assessed by a sensor device, built housing two flexible force transducers in a plastic structure that was positioned in between the first molars teeth. The two recorded force signals become the spatial coordinates of a cursor on a PC monitor.The subject is asked to perform a maximal left, right and bilateral jaw closure effort, in order to draw the boundaries of his bidimensional "working area" (WA) (Fig.1). Then, by modulating the force on the two sides, the subject could steer the cursor (x) so as to match the position of a displayed target (t), randomly generated within his WA(Fig. 1). Three 23-targets sequences were generated, each target remaining displayed for 5 s and alternated with 5 s of rest. The sequence was repeated in a second session on a different day. Matching errors were measured by the mean cursor-target distance (MD), and the distance between the mean cursor position and the target (offset error, OE).(fig.1). These were also evaluated in relative terms, and expressed in percentage of the target force level. Statistical analysis was performed with 2-way ANOVA for repeated measures with DAY (2 levels) and TRIAL (3 level) as factors.

RESULTS: The subjects showed a wide range of WAs, geometrically representing functional aspects like maximal force, and left/right independence in force generation. The subjects learned easily how to drive the cursor on the screen, although the fine control of its position resulted to be quite difficult to achieve. The relative error MD exhibited a significant progressive decrease in the second session: 16.0 +/- 7.9 % (averaged on all subjects, all trial, first day) to10.6 +/- 5.2 % (second day) suggesting the presence of a learning process in the use of the device.

CONCLUSION: The tested system appears to be a useful tool to extend the functional investigation on the masticatory function. It could be also adapted for specific rehabilitation programs mainly in the dentistry field. For a diagnostic use should be taken in account the presence of a learning curve.

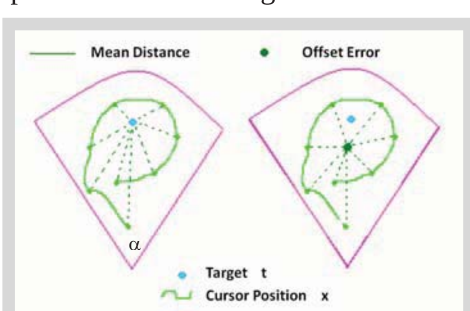

Figure 1: Example of working area and scheme for the calculation of mean distance (MD) and offset error (OE)

ASSESSING THE ACCURACY OF EMG DECOMPOSITION

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AIM: If EMG decomposition is to be useful as a tool for scientific investigation, it is essential to know whether the results are accurate. Because of background noise, waveform variability, MUAP indistinguishability, and perplexing superpositions, this is not always easy to tell. Investigators who use decomposition are faced with several questions: How can I be sure that the results obtained for this particular signal accurately reflect the true motor-unit firing behavior? How can I know whether a particular decomposition algorithm performs as well on my signals as it did in reported validation studies? Even if I have confirmed the results by careful manual inspection, how can I convey my sense of confidence convincingly to others?
METHODS AND RESULTS: Inaccuracy can arise in decomposition not only because of mistakes made by the algorithm or human operator, but also because of inescapable uncertainty in the face of signal variability and complexity. When the true composition of a signal is not known, decomposition accuracy can only be assessed in terms of the degree to which the decomposition is self consistent, physiologically plausible, and adequate to explain the entire signal. This lecture will discuss several approaches and issues in accuracy assessment, including cross-checking simultaneously recorded signals, measures of MUAP waveform and firing consistency, measures of signal complexity and decomposability, and a-posteriori assessment of decomposition accuracy. The latter is a promising new approach that integrates all the shape- and firing-time-related information in the signal to estimate a statistically rigorous level of confidence in the accuracy of each discharge in the decomposition.
CONCLUSION: For some signals, we can be highly confident that decomposition results are accurate and faithfully reflect actual motor-unit behavior. For other signals, we cannot be certain. Better methods for assessing and reporting decomposition accuracy will help ensure the scientific validity of studies that use EMG decomposition.
ACKNOWLEDGEMENT: Supported in part by grant 5R01NS051507 from the US National Institute of Neurological Disorders and Stroke.

ABDOMINAL MUSCLE ONSET AFTER LOW AND HIGH LOAD EXERCISES IN CHRONIC LOW BACK PAIN PATIENTS

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AIM: Delayed onset in deep abdominal muscles has been associated with LBP. Onset in the abdominal muscles in response to rapid arm flexion was in this study investigated before and after 8 weeks with specific low or high load motor control exercises or general exercises in LBP patients.
METHODS: Subjects (n=109) with chronic non-specific LBP of at least three months duration were included and randomly assigned to (1) low-load ultrasound-guided abdominal drawing-in maneuver (ADIM) exercises, (2) high-load stabilizing exercises in slings or (3) general exercises in groups. Primary outcome was the first triggered onset of muscle activity, as recorded by m-mode ultrasound, in the deep abdominal muscles in response to the rapid arm flexion test.
RESULTS: No overall group or time effects were found and within group changes in onset were <12ms. An association was found between baseline onset and change in onset after the intervention (R^2=0.27), most likely reflecting regression toward the mean, Fig. 1.
CONCLUSION: This RCT is the first large-scale study to record changes in deep abdominal muscle onset after specifically tailored exercises. The results give no evidence for effects of low load ADIM exercises on muscle onset. Specific motor control exercises aimed to improve control and stability of the lower spine seem not to work through changes in anticipatory feedforward mechanisms, although effects need to be scrutinized in subgroups showing delayed latency time.

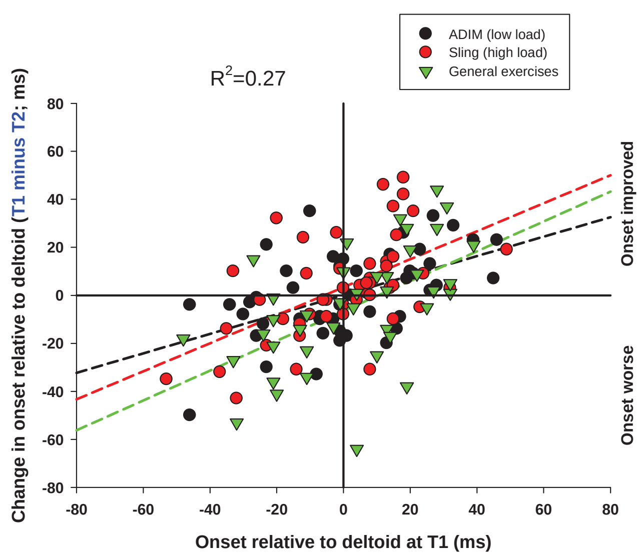

Figure 1: Association between baseline (T1) onset and change in onset after the intervention in abdominal muscles for the three groups (positive change values indicate reduced latency time). Onset values are related to deltoid onset during the rapid arm flexion test. Groupwise regression lines are provided

FINE CONTROL OF INDEX FINGER FLEXION FORCES IS ALTERED WITH CONTACT POINT ALONG THE FINGER

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AIM: To determine how changing the contact point along the index finger that presses against an external object influences the ability of young adults to produce steady forces during static finger flexion tasks.
METHODS: Subjects (n=21; 21.4±3.8 years old) pressed downward with the palmar side of their extended index finger onto a wooden dowel (diameter = 11.1 mm) that was attached to a 6-axis force/torque sensor (ATI Industrial Automation, Nano17). Each subject performed maximal finger flexion forces (MVCs) with the contact point at the tip of the finger, and at the distal (DIP) and proximal (PIP) interphalangeal joints. Following the MVCs, subjects were instructed to hold a constant force at 2.5% and 10% of their MVC for 13 seconds. Subjects received visual feedback of the force produced on a 24-inch LCD monitor placed 1 m from the subjects. Subjects were instructed to keep the force trace as close as possible to the target line at 2.5% and 10% of MVC. Two trials were performed at each of the three contact points. Static steadiness trials were performed with and without visual feedback. No differences were observed between conditions; therefore the following results are presented combining the two visual feedback conditions.
RESULTS: There was no change in MVC force between the tip of the finger (44.8±1.15N) and the DIP joint (44.64±1.19N), however MVC at the PIP joint (40.22±1.06N) was significantly lower than both the tip of the finger and the DIP joint ($p<0.05$). Also, there was a significant increase ($p<0.05$) in the standard deviation (SD) and coefficient of variation (CV) of force at the PIP joint compared to both the DIP joint and the tip of the finger during the steadiness task (see Table 1).
CONCLUSION: We found lower force output and more variability in force when pressing at the PIP joint compared with the DIP joint and the tip of the finger. Previous work has reported that moving the contact point proximally from the tip of the finger to the DIP and PIP substantially increases the relative contribution of intrinsic hand muscles to the task. The current data suggest a lack of extrinsic muscle support at the proximal contact point increases variability of force output during an index finger flexion task. This finding suggests that the extrinsic hand muscles, and not the smaller intrinsic hand muscles, play the predominant role for fine motor control during finger flexion tasks.
ACKNOWLEDGEMENT: Hillary Gruszka, Jon Hubbard, Ryan Kern

Table 1: Variability of force during static flexion tasks at the tip of the index finger (Tip), and the distal (DIP) and proximal (PIP) interphalangeal joints.

Contact point	Variable	2.5%	10%
Tip	**SD (N)**	0.022±0.015	0.064±0.041
	CV (%)	1.758±1.013	1.583±0.898
DIP	**SD (N)**	0.026±0.018	0.070±0.050
	CV (%)	1.981±1.129	1.793±1.207
PIP	**SD (N)**	0.039±0.031*	0.089±0.067*
	CV (%)	3.626±2.420*	2.515±1.986*

***PIP significantly different than Tip and DIP at p<0.05**

REHABILITATION OF THE HEMIPARETIC GAIT SUPPORTED BY NOCICPETIVE WITHDRAWAL REFLEX STIMULATION

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AIM: To investigate the therapeutic use of nociceptive withdrawal reflexes to support gait training in the acute post-stroke phase.
METHODS: Individuals who have had a cerebrovascular accident 2-6 weeks before inclusion time were randomly divided into two groups: a treatment group that received intensive physiotherapy-based gait training supported by withdrawal reflex stimulation synchronized to the gait cycle, and a control group that received intensive physiotherapy-based gait training alone. Electrical stimuli delivered to the arch of the foot were used to elicit the withdrawal reflex at heel-off with the purpose of facilitating the initiation and supporting the execution of the swing phase. Gait quality was assessed by the Functional Ambulation Category (FAC) test and by the preferred and maximal walking velocities before treatment, and immediately after, one month and six months after finishing treatment.
RESULTS: Subjects in the two groups showed an improvement in their walking ability, as assessed by the FAC-test. The subjects who received withdrawal reflex stimulation had a tendency to score better in the FAC-test and to walk faster at their chosen velocity, compared with the patients in the control group. No differences between the groups were observed when comparing the maximum gait velocity.
CONCLUSION: Intensive physiotherapy training combined with electrical activation of the nociceptive withdrawal reflex seemed to improve the walking ability of hemiparetic patients and might be useful in the rehabilitation of the hemiparetic gait.
ACKNOWLEDGEMENT: This work was supported by The Sven Andersen Fond and the Danish Research Council for Technology and Production Sciences. The authors wish to thank physiotherapists Bodil Otossen, Jørgen Larsen, and Helle R. M. Jørgensen from Brønderslev Neurorehabilitation Center, Vendsyssel Hospital for their work during the training and evaluation sessions.

THE ROLE OF TRANSVERSUS ABDOMINIS AND ERECTOR SPINAE IN BACKWARDS ROCKING IN FOUR POINT KNEELING

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AIM: Backwards rocking in four point kneeling is used during assessment of lumbar stability dysfunction. Understanding of muscle activity during this clinical test can form the foundations of a validated test. This study reports the affect of backwards rocking in four point kneeling on the muscle activity of Transversus Abdominis / Internal Oblique (TrA/IO) and erector spinae (ES).
METHODS: An asymptomatic convenience sample (n=15) was recruited (mean age 23 years). Participants with a history of lower back or leg pain (< two years) or trauma to the lumbar spine (< six months) were excluded. Myoelectric activity of the TrA/IO and ES were obtained using a repeated measures design. Surface EMG electrodes measured the amplitude of muscle activity at the start, middle and end of movement (Hermens, Freriks, Disselhorst-Klug and Rau, 2000; Marshall and Murphy 2003). Loss of lumbar spine neutral (5 degrees either side of the start position) and change in hip angle were measured using electrogoniometry.
RESULTS: Data was not normally distributed. There was no significant difference ($p = 0.922$ Kruskal-Wallis) in mean IEMG activity of TrA/OI between start (16.52 [SD2.13]), middle (25.3 [SD3.78]) and end points (25.8 [SD3.89]). Mean IEMG of ES was significantly increased ($p=0.00$, Kruskal-Wallis) between start (0.89 [SD1.16]), mid (1.78 [SD1.66]) and end points (2.37 [SD1.71]). Pairwise comparison (Mann-Whitney test with Bonferroni correction to $p = 0.0167$), showed a significant difference in myoelectric activity between start and mid points ($p = 0.000$), start and end points ($p = 0.00$) and no significant difference between mid and end points ($p = 0.023$). Loss of lumbar spine neutral (5 degrees movement) occurred at 100° of hip flexion.
CONCLUSION: As previously reported (Hodges, 1999) activity of the lower fibres of TrA/IO does not change as a result of dynamic movement. ES is more active at the mid and end points of movement and is activated in response to dynamic movement. ES works eccentrically to control flexion of the spine contributing to dynamic control. These findings complement those of Colloca and Hinrichs (2005) and Hodges (1999). Loss of lumbar spine neutral occurred at 100° of hip flexion 20° earlier than previously reported (Comerford and Mottram, 2001). Further work is required to validate backwards rocking in four point kneeling.
ACKNOWLEDGEMENT: This study was completed as a requirement of the MSc (PreReg) Physiotherapy at Northumbria University by Sarah Dickenson.

APPLICATIONS OF EMG DECOMPOSITION

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AIM: EMG decomposition is a powerful tool for studying neurophysiological phenomena ranging from the conduction velocity of muscle fibers to the behavior and architecture of motor units (MUs) to the coordinated activity of the motoneuron pool. This lecture will present some of the investigations we have performed in Palo Alto using EMG decomposition.
METHODS: EMG signals are recorded simultaneously from several sites in a muscle using fine-wire and needle electrodes. All electrodes have about 1 mm of exposed conductor, providing reasonably decomposable signals up to about 30% MVC. The wires tend to remain in place, making it possible to recognize the same MUAPs in multiple contractions. The needles facilitate sampling a wider territory. The wires are inserted as pairs, but recorded individually to increase yield. All signal are recorded monopolarly to capture volume-conducted potentials generated at the endplate and muscle-tendon junction. The signals are recorded with wide bandwidth (5 Hz - 5 kHz) but digitally high-pass filtered (1 kHz) to accentuate the spikes for decomposition. Full decomposition sometimes requires thorough manual editing to ensure completeness and accuracy. MUAP waveforms are averaged from the unfiltered signals at each recording site to obtain the propagation pattern of each identified MU.
RESULTS: Changes in muscle-fiber conduction velocity after recruitment and in response to fluctuations in firing rate can be studied by measuring the latency between spikes from the same MU recorded at two different sites in the muscle. The location of the MU endplate and muscle-tendon junction can be determined from the propagation pattern and the latencies of the MUAP onset and terminal wave. Some MUAPs have more than one propagating wave, indicating separate groups of muscle fibers innervated by different branches of the same motoneuron. Some MUAPs have satellite potentials, whose origin can be determined from their latency with respect to the other MUAP landmarks. In series-fibered muscles, some MUAPs have unstable components arising from doubly innervated muscle fibers. During non-isotonic contractions, recruitment can be quantified by counting the number of MUs active in each interval of time to study the differential control of recruitment and rate coding. With 3 fine-wire pairs, it is not difficult to detect 30 or more different MUs in the same muscle, and thus to study the relative architecture and coordination of populations of MUs. With electrodes in different muscles it is possible to study the coordination of different motoneuron pools during simple static and dynamic tasks.
CONCLUSION: EMG decomposition, if utilized with sufficient attention to accuracy, can provide detailed information across several levels of the human nervous system.
ACKNOWLEDGEMENT: Supported by the US Department of Veterans Affairs and grants 5R01AR049894 and 5R01NS051507 from the US National Institutes of Health.

EFFECTS OF ALTERED PERCEPTION ON MOTOR CORTICAL EXCITABILITY IN A HYPNOTICOMOTOR TASK

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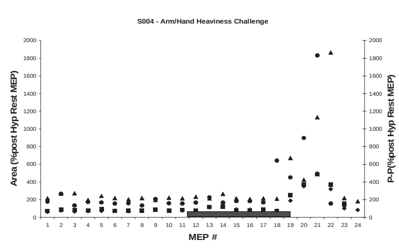
AIM: A large percentage of classic hypnotic effects involve alterations in the perception of control of motor movements. Typical challenge tasks under hypnotic suggestion can be described as: 1) an arm stiffness task where the subject is led to perceive that their arm has become very stiff and then they are challenged to “try to bend it” and 2) an arm/hand heaviness task where the subject is led to perceive that their arm/hand has become very heavy and then challenged to “try to lift it”. Previously we have proposed that burst activity in the prime movers of the elbow would decrease (or not change) during the challenge portion if the primary motor cortex was not engaged in the action demanded by the challenge. We found that in 7 of 12 highly hypnotizable subjects burst activity was either non-existent or too short (less than 300 ms) to be considered volitional during the tasks. In this study we attempt to characterize the engagement of the motor cortex using TMS stimulation of primary motor cortex (M1) Motor cortical excitability as assessed by transcranial magnetic stimulation (TMS) over the primary motor cortical area for Biceps and Triceps Brachii was our primary objective. Here we present preliminary results.
METHODS: Subjects were prescreened for hypnotizability using a standardized of Hypnotizability (HGSHS:A). This is a 12 point scale and subjects for this study were selected if they scored 10 and above. A transcranial magnetic stimulator (MagStim) was used to locate the optimal area for stimulation for both Biceps and Triceps Brachii where motor evoked potentials (MEP’s) were acquired via surface electrodes. Custom designed software (Labview Systems) was used to derive the area and peak-to-peak data of the MEP and which was sampled at 2KHz.
RESULTS: Preliminary data on 4 highly hypnotizable subjects indicates variable effects of this altered perception. The behaviour of one of the subjects is graphically indicated below. In this subject the suggestion of stiffness resulted in very little change in Biceps MEP while the Triceps MEP potentiated considerably during the challenge to bend the arm. On the other hand very little change was evident in both Triceps and Biceps MEP’s during the arm heaviness challenge. The very high potentiation shown below was evidenced to a much lesser degree in the other three subjects with MEP’s achieving as much as 300% of post hypnotic resting MEP’s
CONCLUSION: Evidently the suggestion of experiencing a very stiff arm and then challenged to try to bend it or being told that their arm was immobile and being asked to move it results in varying engagement of the primary motor cortex.



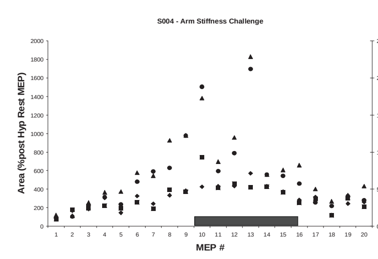


Figure 1: An example of Biceps and Triceps MEP hypnoticomotor responses to the suggestions of bending or lifting the arm the gray box indicates the period during which the participants were attempting the command.

SURFACE DISTRIBUTION OF MUAPS IN A PENNATE MUSCLE

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AIM: One of the important accomplishments of high-density surface EMG (HDsEMG) has been to estimate the location of the innervation zone and the mean muscle fiber conduction velocity in long muscles with fibers parallel to the skin surface. The anatomical information that HDsEMG can provide for pennate muscles is less well understood. This study investigated the surface representation of motor-unit action potentials (MUAPs) in the biceps femoris muscle, a pennate muscle of the thigh.
METHODS: Five subjects (four males, one female, aged 28-50 years) lay prone with the knee flexed 45° from full extension. An array of surface electrodes (13 rows × 5 columns with 8 mm inter-electrode distance) was placed along a line from the ischial tuberosity to the lateral side of the popliteal fossa. HDsEMG signals were recorded in monopolar fashion from 4 columns during low-force isometric contractions. Intramuscular EMG (iEMG) signals were recorded simultaneously from 3 sites along the middle column using needle electrodes. The iEMG signals were decomposed into their constituent MUAP trains, and the corresponding surface MUAPs were averaged from the HDsEMG signals.
RESULTS: The monopolar surface MUAPs were largely standing waves—they had approximately the same characteristic biphasic shape at every spatial location, although the amplitude varied considerably and changed sign in the proximodistal direction (Fig. 1). They were largest distally, where they had a positive-negative configuration. The spatial variation was different for different MUs giving each MU a unique spatial signature.
CONCLUSIONS: Biceps femoris is a pennate muscle with relatively short fibers that are inclined obliquely to the surface and terminate on a superficial distal aponeurosis. The two phases of the surface MUAPs correspond to (1) the initiation and propagation of the action potential and (2) the termination of the action potential at the distal aponeurosis. The different signatures show that different MUs terminate at different proximodistal levels. Features of the surface MUAPs, such as the proximodistal levels of the phase inversion and maximum amplitude, may be useful for estimating the anatomical characteristics of individual MUs in this pennate muscle. However, this estimation will be complicated by the oblique anisotropy of the muscle and the thickness of the subcutaneous fat.
ACKNOWLEDGEMENT: Supported in part by the US Department of Veterans Affairs and grant 5R01NS051507 from the US National Institutes of Health.

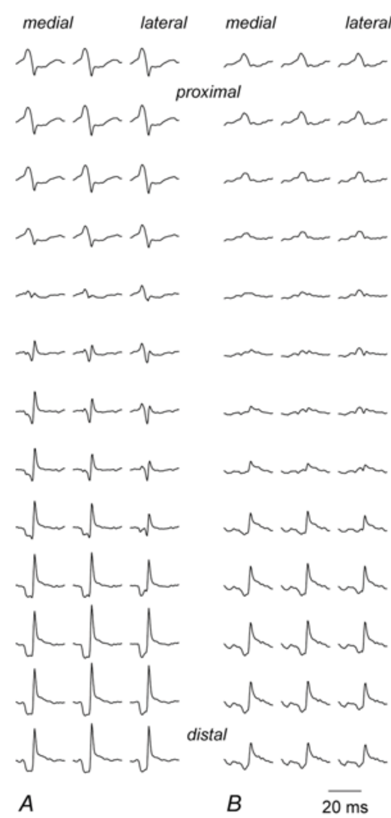

Figure 1: Two surface MUAPs. in monopolar configuration.

TOWARDS REAL-TIME ACTIVE PATHOLOGICAL TREMOR COMPENSATION USING FUNCTIONAL ELECTRICAL STIMULATION

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AIM: The objective of this paper is to present the current research works on development of real-time active pathological tremor compensation via functional electrical stimulation (FES).
METHODS: The strategy used in the project was to control FES stimulation parameters to generate anti-phase movement to the tremor. The works could be divided into 3 main areas; sensing, signal processing and analysis and the FES control and actuation. The sensing system is to acquire required data for the FES control. Accelerometer (ACC) and surface electrode electromyography (EMG) were explored as the main sensors. The acquired data will then have to be analyzed and processed well to extract useful information for the FES control. The main issues in the signal processing and analysis are fusing both signals to predict tremor parameters, separating intended motion and removing the FES stimulation artifact (SA) and M-wave from the recorded EMG signal. Kalman filter (KF) and extended kalman filter (EKF) were evaluated for the sensor fusion to characterize the tremor phase and amplitude. While tremor frequency was derived from the recorded EMG signal using weighted-frequency Fourier linear combiner (WFLC) algorithm. EKF with the help of adaptive high pass filter were used to separate intended motion in the recorded EMG signal. As to suppress SA and M-wave, software blanking and comb filter were implemented. Since the actuation system is the tremulous body part itself, the system behavior has to be known to control its motion. A musculoskeletal system has been modeled using 2nd order systems for the muscle model and the joint model, but has not been implemented to control the FES stimulus. Another model was developed using curve-fitting method derived experimentally and has been implemented an open-loop FES control. The later model was then evaluated experimentally to a tremor patient.
RESULTS: The sensing system was able to acquire required tremor data. EKF was avaluated and gave more satisfactory results than KF in predicting the amplitude and the phase of the tremor. Tremor frequency was also predicted well using WFLC algorithm. Intended motion components was removed well from the recorded EMG signal using EKF algorithm and adaptive high pass filter developed. Software blanking and comb filter were used to remove the SA and M-wave contaminating the EMG signal recorded. The open-loop control was implemented using model developed using curve-fitting method. By manually adjusting the stimulation parameters with predetermined constant amplitude-modulated frequency, pulse width and inter pulse period, reduced tremor amplitude was observed.
CONCLUSION: The sensing and signal processing algorithm developed can characterize the tremor well and fulfil the real-time needs. The future works will focus on the musculoskeletal modeling and the closed-loop FES controller design for the control and actuation part to achieve the ultimate goal of developing an automated orthosis for real-time pathological tremor compensation.
ACKNOWLEDGEMENT: We would like to thank Markus Rank for the development of musculoskeletal modeling during his attachment in the lab, and Shruti Mehta Jitendra for her dissertation on the open-loop FES control. We would also like to thank Zhang Dingguo and Kalyana C Velovolu for their contribution to the group during their postdoctoral in the lab.

ACTIVATION TIMING OF THE ERECTOR SPINAE AND MULTIFIDUS DURING FLEXION-RELAXATION OF THE SPINE

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AIM: Surface EMG recordings of the erector spinae group (ES) are frequently been used as a surrogate for multifidus (MF) activation in biomechanical investigations. However, a direct comparison has not been performed to justify this assumption. Therefore, the objective of the investigation was to examine differences in activation timing between surface EMG recordings of the ES and fine wire EMG recordings of the MF.
METHODS: Fourteen volunteers performed flexion-extension trials consisting of 3 sec flexion from neutral standing, 3 sec pause in deep flexion, and 3 sec extension back to neutral standing. 3D orientation of the torso and pelvic segments were defined by reflective markers affixed to bilateral ASIS and PSIS, C7, T10, and sternum. Lumbar flexion angle was defined as the torso angle projected onto the sagittal plane of the pelvic coordinate system. Following routine EMG skin preparation and subsequent sterilization, 50µm fine wire pairs were inserted bilaterally into the MF at the L3L4 level. Ag-AgCl surface electrodes were placed above the ES with an interelectrode distance of 4cm to accommodate for fine-wire recording. Analog data were preamplified and subsequently amplified up to 5k. Raw EMG data from each channel were bandpass filtered from 10-500Hz, full-wave rectified, and smoothed with a 10Hz low pass filter (zero phase-lag 4th order Butterworth) to create the EMG linear envelop. Threshold of activation onset and termination was set as 10% of maximum amplitude for each trial. Muscle activation timing was expressed as the lumbar flexion angle normalized to maximum flexion angle of the trial. Differences between muscles were assessed using mixed model statistics.
RESULTS: The EMG profiles demonstrated a typical flexion-relaxation response with termination of the signals after reaching full flexion and onset of the signals to facilitate extension movement (Figure 1). Activations normalized to lumbar flexion angle indicated that the ES had 4.1% later termination during the flexion phase (p=0.008) and 1.5% earlier onset in the extension phase (p=0.032) than MF. Mean(SE) differences in time were 96.8(32.1) and 64.3(11.8) msec for termination and onset, respectively.
CONCLUSION: These results indicate the existence of significantly prolonged periods of activation in the ES. This corresponds with the comparatively longer lever arm of the ES and may necessitate larger forces and longer activation for requisite flexion and extension movements.
ACKNOWLEDGEMENT: Supported by NIH K99 AT004983-01A and NIOSH MAP ERC Pilot Award.

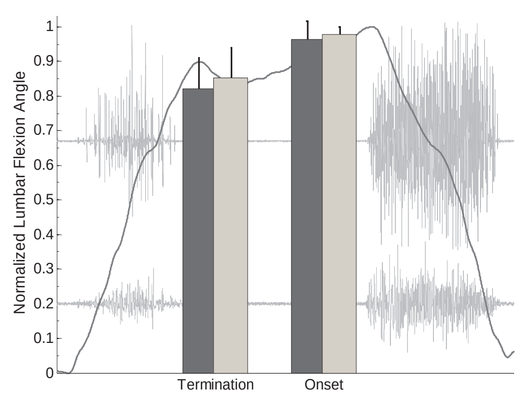

Figure 1: Activation profiles of ES (light bar) and MF (dark bar), termination and onset expressed as normalized lumbar flexion angle.

FATIGUE SYMPTOMS INVESTIGATED IN A LOW-LOAD REPETITIVE WORKING TASK OF LONG DURATION

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AIM: Upper extremities muscle-skeletal disorders are an emerging occupational syndrome with high social an economical impact whose underlying pathophysiological mechanisms are still largely unknown. Repetitive movements, even at low working loads, are a recognized risk factor. By means of non invasive techniques, muscle function was monitored during a controlled low-load repetitive flexo-extension task, aiming at detecting early changes in different fatigue indexes and at measuring their time course during recovery.
METHODS: Sixteen subjects performed a wrist flexo-extension task: +/- 30 deg, 1 cycle/s, peak torque=10% maximum voluntary contraction (MVC), 1-h duration divided in 10 slots of 5.5-min work + 0.5 min rest. Surface electromyogram was detected from extensor carpi radialis longus (ECRL) and brevis (ECRB) and flexor carpi radialis (FCR) muscles. EMG signals were acquired during the dynamic task as well as during test isometric contractions (5% MVC, 20 s) performed before and 0, 30 and 50 min after the dynamic task. Amplitude (RMS) and spectral (MNF) parameters were extracted from the EMG signals in both conditions. In addition, the occurrence of low frequency fatigue (LFF) was assessed by changes in T_{20}/T_{80} (the ratio of the torque developed by extensor muscles when stimulated at frequencies of 20 and 80 Hz)
RESULTS: Little or no fatigue was perceived by the subjects at the end of the task. EMG variables exhibited large variability and small average changes throughout the dynamic task, only MNF exhibiting a significant decrease in ECRB (-2.54±4.1%, $p<0.05$). Signs of myoelectric fatigue were detected in the isometric test contractions: with respect to control, MNF decreased in ECRB at 0 and 30 min after the task (10.90±13.73%, $P<0.05$ and 6.59±13.93%, $P<0.05$, resp.), whereas no significant changes were observed for RMS. Similar effects were observed in ECRL. The T_{20}/T_{80} ratio exhibited a early decrease already at 6 min after the beginning of the task (-14.38±12.38%, $P<0.05$), decreased by 30.44±20.96% ($p<0.05$) at the end of the task, and did not recover in the following 50 min. LFF was consistently observed among subjects and was not correlated with changes in MNF and RMS computed in static and dynamic conditions.
CONCLUSION: A low-load repetitive working task performed for a duration of 1h can induce detectable changes in fatigue indices. Myoelectric effects lasted up to 30 min after the exercise, while LFF outlasted the 50-min recovery period. The complex muscle anatomy in the forearm makes accuracy in EMG recordings difficult and may account for part of the variability in EMG variables. Uncorrelated changes in myoelectric fatigue indexes and in LFF seem to reflect different fatiguing processes in working muscles.

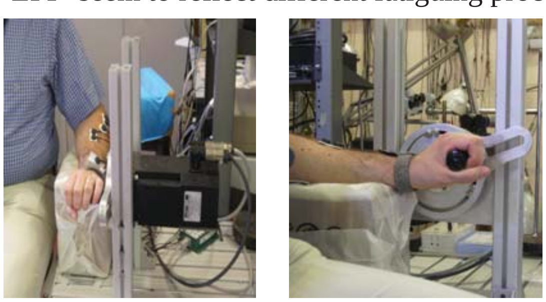

Figure 1: Experimental setup with one subject performing the wrist flexo-extension task by holding a handle connected to the servo-controlled motor (Sensodrive, Wessling, DE)

MONITORING MUSCLE FATIGUE VIA AREA/AMPLITUDE RATIO (Raa)

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AIM: In this study we investigated the use of the Raa parameter (Area/Amplitude Ratio) computed from the surface electromyogram (SEMG) to monitor the neuromuscular fatigue and addressed a comparison between Raa and Wavelet derived parameters - Instantaneous Mean Scale (IMS) and Instantaneous Median Scale (IMedS) - with the purpose to assess its use and computational efficiency as an alternative instrument.
METHODS: The subjects (n=12) sitting on a chair, with a 90^o anteflexion between the forearm and the arm, had to push against a force transducer, in flexion. The 100% MVC was estimated, as the maximum force that could be sustained for two seconds. Tests were performed at 50% MVC up to exhaustion. A pair of SEMG electrodes (H59P, MVAP, USA) were placed on the Biceps. The SEMG signals were amplified (x 2000, 100 MΩ input impedance, 100 dB CMRR, 250 Hz antialias filter, Beckman R611, USA) and acquired via a computerized acquisition system (DAP1200 Microstar Laboratories USA), at 1000 samples/second. Raa – Average Area /Amplitude Ratio, with a dimension of time [ms], was computed from the SEMG (electromyographic signal) in the time domain, as an average of the Area/Amplitude ratios over the considered epoch, calculated between consecutive transversals of the isoelectric line, called ‘phases’. IMS, IMedS were computed from SEMG via the Continuous Wavelet Transform (30 scales, ‘Mexican hat’ mother wavelet). Raa, IMS, IMedS were computed on epochs of 100 ms. A linear regression was performed on the data.
RESULTS: Raa, IMS and IMedS increased (Figure 1) in all subjects, from the beginning of the contraction. This proves the central component of the fatigue. The two-way analysis of variance (ANOVA) showed no significant differences in the average slopes, between sexes, for Raa, IMS, IMedS respectively (p=0.05). Computationally, Raa was 5.52±.97 times quicker to compute than IMS, IMedS. For the given number of scales considered (30) IMS, IMedS – computed from WT – required 285±57 times larger memory than needed for Raa.
CONCLUSION: As hypothesized, the experiments showed a steady increase of Raa, IMS and IMedS during the development of neuromuscular fatigue from the beginning of the contraction to exhaustion, due to a central intervention in modulating the muscle activation with increasing fatigue. Raa has a similar behavior with IMS and IMedS, encouraging its use in monitoring of the fatigue, with computational advantages.
ACKNOWLEDGEMENT: This work was performed under research grant 82108/2008-CNMP/Romania.

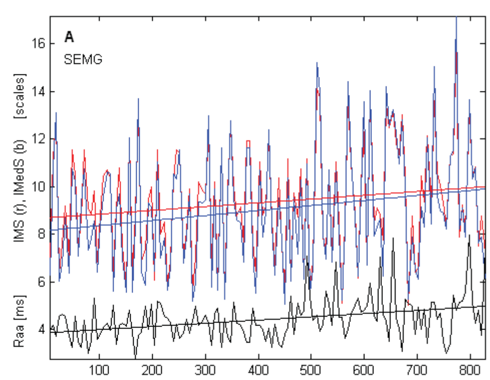

Figure 1: The evolution of Raa, IMS, IMedS (blue) with advancing fatigue.

RIGOROUS A-POSTERIORI ASSESSMENT OF ACCURACY IN EMG DECOMPOSITION

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AIM: Accuracy assessment is essential for judging whether scientific measurements are trustworthy and thus whether inferences drawn from them are based on objective reality or only wishful thinking. In the case of EMG decomposition, accuracy assessment is difficult because of the complicated nature of the EMG signal. Even if an algorithm has been shown to be accurate in simulations, how can we be sure it is as accurate for the signals at hand?
METHODS: We have developed a rigorous statistical method for assessing the accuracy of a given decomposition based only on evidence from the signal itself. The method uses statistical decision theory in a Bayesian framework. It integrates all the shape- and firing-time-related evidence provided by the signal to compute the posterior probability that the decomposition is correct, based on the estimated statistical properties of the MUAPs and noise and taking into account the relative likelihood of every other possible decomposition. If it is very unlikely that any other decomposition could have produced the signal, the decomposition can be accepted as accurate with a high degree of confidence. Otherwise it cannot. The method ultimately provides a level of confidence in the accuracy of each discharge in the decomposition. We tested it on 3 simultaneously recorded pairs of real EMG signals (from brachioradialis, biceps femoris, and tibialis anterior muscles) with 4-7 active MUAP trains per signal, of which 4 or 5 were common per pair. The signals were decomposed independently by a human expert, and the results cross-checked between pairs. Each decomposition was then analyzed using the proposed method.
RESULTS: The a-posteriori (AP) analysis rated 4521 of 4678 discharges as correct decomposed to within ± 0.5 ms with a confidence level of 99%. Cross-checking between signal pairs confirmed that all these ratings were appropriate. The AP analysis rated 117 discharges as only accurate to within ±5 ms and 29 as uncertain. These mostly involved very small MUAPs or noise glitches. It also identified 6 likely decomposition errors. Upon re-inspection, the human expert found that 4 of these were indeed decomposition errors, while the other 2 were type I errors of the AP analysis. These results show that, at least for these relatively simple signals, the accuracy assessment provided by AP analysis is consistent with that of a human expert and with that attainable by cross-checking.
CONCLUSION: AP analysis provides an objective and statistically rigorous way to prove the decomposition accuracy of real EMG signals whose true composition is not otherwise known. It is hoped that this type of analysis can serve a similar function for EMG decomposition as confidence intervals and tests of statistical significance serve for other scientific measurements: to provide a solid justification for further inferences when there is reasonable certainty and a safeguard against faulty inferences when there is reasonable doubt.
ACKNOWLEDGEMENT: Supported by the US Department of Veterans Affairs and grant 5R01NS051507 from the US National Institute of Neurological Disorders and Stroke.

M-WAVE, H-REFLEX AND ASYNCHRONOUS MOTOR UNIT ACTIVITY EVOKED BY NMES APPLIED OVER A NERVE AND OVER A MUSCLE

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AIM: Neuromuscular electrical stimulation (NMES) can be delivered over the nerve trunk (nerve stimulation) or over the muscle belly (muscle stimulation) to generate contractions. Preliminary work at low stimulation intensities suggests that contributions from *peripheral* and *central* pathways to contractions differ between nerve and muscle stimulation. Quantify *peripheral* and *central* contributions to evoked contractions during nerve and muscle stimulation at functionally relevant contraction amplitudes.
METHODS: Ten able-bodied participants were tested. Stimulation was delivered over the posterior tibial nerve in the popliteal fossa (nerve stimulation) and over the triceps surae muscle belly (muscle stimulation). NMES (1 ms pulses) was delivered at 20 Hz for 8 seconds and was adjusted to produce between 20-30% maximum voluntary torque (MVT) 2-3 seconds into the stimulation. Electromyography (EMG) responses evoked by nerve and muscle stimulation were compared at the beginning ($Time_1$; 2 to 3 seconds into the stimulation) and end ($Time_2$; 6 to 7 seconds into the stimulation) of each stimulation train. H-reflexes and M-waves were measured peak-to-peak and normalized to the maximal M-wave (M_{max}). Asynchronous activity was measured using root mean squared (RMS) of EMG activity recorded during a 10 ms window immediately before the H-reflex and was normalized to maximum RMS calculated from EMG recorded during a maximal volitional contraction.
RESULTS: Torque did not differ between nerve and muscle stimulation. On average, torque at $Time_1$ was 24% MVT while torque at $Time_2$ was 26% MVT. M-waves were largest during muscle stimulation compared to nerve stimulation and were on average larger by 40% M_{max} at both $Time_1$ and $Time_2$. H-reflexes were largest during nerve stimulation compared to muscle stimulation and were on average larger by 9% Mmax at $Time_1$ and $Time_2$. Asynchronous activity was approximately twice as large during muscle stimulation compared to nerve stimulation, but this difference was only observed at $Time_2$.
CONCLUSION: Both nerve and muscle stimulation generated contractions through peripheral (M-wave) and central (H-reflex and asynchronous activity) motor unit recruitment. Contractions evoked by nerve stimulation had a greater contribution from H-reflex pathways, in comparison to direct motor axon activation (M-wave). In contrast, contractions evoked by muscle stimulation showed a predominance of M-wave activity. Only after several seconds of did a *central* contribution emerge during muscle stimulation (asynchronous activity). M-waves utilise a *peripheral* pathway and recruit motor units in a non-physiological manner (Gregory & Bickel, 2005), leaving fatigue-resistant muscle fibres relatively inactive and vulnerable to disuse atrophy. However, activating sensory axons can recruit motor units through a *central* pathway in the form of H-reflexes and asynchronous activity. Both of these central responses recruit motor units synaptically and likely produce muscle contractions that follow a physiological motor unit recruitment order (Henneman, 1957). Augmenting electrically evoked contractions through *central* pathways should produce more fatigue resistant muscle contractions compared to those generated by motor axon activation alone. These data suggest that nerve and muscle stimulation may have particular advantages depending on the objective for NMES rehabilitation. We are currently investigating whether these findings translate into differences in fatigue resistance.

DISCRIMINANT VALIDITY OF CLINICAL AND LABORATORY MEASURES OF SINGLE AND DUAL-TASK BALANCE PERFORMANCE IN OLDER ADULTS WITH AND WITHOUT HISTORY OF FALLS

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AIM: Postural instability is a major risk factor of falling in the elderly. The force platform posturography is a commonly used method for quantifying balance performance. It is well documented that postural control may decline while performing a concurrent cognitive task and this effect increases with age. This study aimed to determine the ability of various laboratory measures and clinical tests of postural control to identify fallers in elderly population. Additional aim was to identify whether dual task balance performance could discriminate between elderly fallers and non-fallers better than performing the balance task alone.

METHODS: 20 subjects (72.40 ±5.29 years old) who reported having fallen unexpectedly at least one time in the last year, and 35 non-fallers (69.91 ±4.24 years old) participated in the study. Center of pressure (COP) motion was recorded in quiet stance at three levels of difficulty (rigid surface-eyes open, rigid surface-eyes closed, and foam surface-eyes closed), in isolation or concurrently with a concurrent backward counting task. Force plate data was used to calculate center of pressure (COP) parameters including mean total velocity, phase plane portrait, area (95% confidence ellipse), standard deviation (SD) of amplitude, and SD of velocity. The timed up and go test (TUG), The timed up and go test while performing a cognitive task (TUGcog), the functional reach test, the lateral reach test, and the stop walking while talking test were used for clinical balance assessment. A three-way repeated measures ANOVA was used to evaluate differences on the COP parameters between the three levels of postural difficulty, 2 levels of cognitive loading (task, no task), and two groups (fallers, non-fallers). Furthermore, clinical tests results were entered into a logistic regression analysis.

RESULTS: A 2×2×3 (2 groups, 2 cognitive loading, and 3 postural task difficulties) repeated measures ANOVA identified significant main effects for group, postural task difficulty, and cognitive loading ($P<.05$). There were also significant group by postural difficulty, group by cognitive loading, and postural task difficulty by cognitive loading interactions ($P<.05$) .Logistic regression results showed that among the clinical measures of postural control, the TUG time predicted the fall status best (odd ratio, 2.46).

CONCLUSION: Cognitive loading and postural task difficulty both discriminated well between faller and non-faller older adults. Measurement of COP parameters while standing on the foam surface and performing a concurrent cognitive task provided the best discrimination between the two groups. The Most discriminative clinical measure of postural control was the TUG time.

EFFECTS OF TAPING APPLICATION IN TEMPOROMANDIBULAR DISORDERS: A PILOT STUDY

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AIM: Neuromuscular taping is currently regarded by physiotherapists as a method supporting rehabilitation and modulating some physiological processes. This taping method uses a special elastic-like tape over and around muscles and/or joints in order to assist and give support to affected tissues as well as to prevent over-contraction. Starting from these considerations we tried to apply this technique to the temporomandibualr joint. The purpose of this pilot study was to examine the influence of the tape application in subjects affected by temporomandibular disorders (TMD).
METHODS: The study was carried out on ten disc-relatedTMD patients according to the Research Diagnostic Criteria for TMD (RDC/TMD). Each subject participated in testing procedures on 2 different days. The procedure consisted in recording condyles' movements by computerized axiography before taping (T0) and immediately after the application of the tape on the TMJ region of both sides. The second session (T1) was performed three days later after the removal of the tape. VAS scales were administrated during each session.
RESULTS: Results show an improvement in tracings (quality, quantity and characteristics refer to muscular behavior) and pain scales immediately after the taping application.
CONCLUSION: The self-adherent tape could represent a valid support in treating disc-related TMD patients. Further study are necessary to validate this method on TMD patients.

THE EFFECTS OF SPASTICITY AND SYNERGIES ON TARGETED REACHING MOVEMENTS IN CHRONIC HEMIPARETIC STROKE

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AIM: Abnormal movement coordination is often the most debilitating with respect to functional recovery following stroke, but also the least well understood. Medical treatment of post stroke movement impairments is predominantly targeted at spasticity prevention and reduction. Unfortunately, the passive conditions during conventional spasticity measurements do not resemble those during voluntary movements such as lifting or reaching. This neglects the influence of other impairments such as the abnormal coupling of shoulder and elbow joint torques (also known as movement synergies) on the observed stereotypic and awkward movements of the impaired arm. The aim of this study is to quantify the influence of center-out voluntary ballistic reaching movements at different levels of shoulder abduction loading on the expression of spasticity at the elbow.

METHODS: Voluntary reaching consists of two active elements: maintaining arm posture against gravity and making the actual reaching movements. These may have different effects on the expression of spasticity. We added a powered degree of freedom at the elbow to our ACT-3D system (see Figure 1) to control the amount of lifting torque generated in the shoulder and to perturb the elbow to elicit stretch reflex responses from our stroke subjects during their voluntary reaching movements.

Figure 1: ACT-4D with the Elbow Perturbator, based on the MOOG's HapticMaster.

RESULTS: Preliminary results show that the measured resistance torque against the stretch perturbation increases with shoulder load (not shown here). Figure 2 shows the simultaneous increase of the maximum EMG response, likely due to the expression of the flexion synergy.

CONCLUSION: The observed stereotypic and awkward movements of the impaired arm—often attributed solely to spasticity—are more likely caused by the expression of abnormal coupling of shoulder and elbow joint torques.

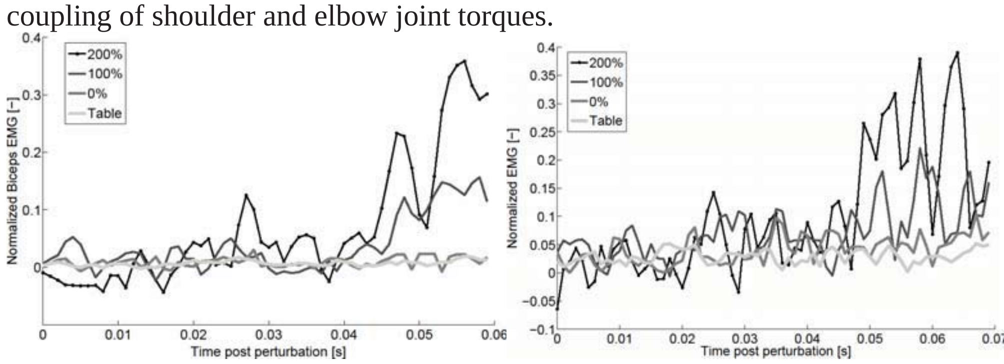

Figure 2: EMG time-profiles of the reflex response (normalized to maximum) without (left) and with (right) voluntary movement for a moderately affected subject. In both plots, the maximum EMG response increases with shoulder load.

IMMEDIATE AFFECT OF VALGUS UNLOADER BRACING ON PERIARTICULAR MUSCLE ACTIVATION PATTERNS IN MODERATE MEDIAL COMPARTMENT KNEE OSTEOARTHRITIS

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AIM: The objective of this study was to determine the immediate effect of “valgus unloader” braces on periarticular muscle activation patterns during walking for those with moderate medial compartment knee osteoarthritis (OA). The intent was to improve our understanding of the mechanism by which valgus braces improve pain levels.
METHODS: Eighteen patients (56 years, BMI 32kg/m^2) with moderate medial compartment knee OA based on radiographic findings and functional ability, were prescribed a custom fit valgus brace. After standard skin preparation, surface electromyograms (EMG) from seven periarticular muscles (vastus lateralis and medialis, rectus femoris, lateral and medial gastrocnemius, and medial and lateral hamstrings) were digitized at 2000 Hz while participants walked at their self-selected walking speed along a six-meter walkway for randomly assigned brace and no brace conditions. Three-dimensional (3D) motion of the knee was captured using an Optotrak ™ (NDI) motion capture system. EMG signals were full wave rectified, low pass filtered (6Hz) and amplitude normalized to a standard set of maximal voluntary contractions. Joint angles and EMG waveforms were time normalized to 100% of the gait cycle. Five trials were averaged for each waveform. Waveforms for the three angle measures and three muscle groups were input to separate principal component analysis models that extracted the principal temporal and amplitude waveform characteristics in the form of principal patterns. Each principal pattern was scored for each muscle, angle, subject and condition. Repeated measures analysis of variance models ($\alpha=0.05$) on the EMG principal pattern scores tested condition and muscle main effects. Post hoc analysis was performed on significant findings. Paired T-tests tested difference between conditions for the angle scores.
RESULTS: Average walking velocity for both conditions was 1.21 m/s and there were no differences ($p>0.05$) in any stride characteristics between conditions. There were significant condition effects ($p<0.05$) for the gastrocnemius grouping for the principal pattern that captured a phase shift and for the quadriceps principal pattern that captured an increase in burst of activation during early stance. A condition by muscle interaction existed for the hamstring principal component that captured prolonged activation during mid to late stance. Minimal 3D kinematic changes were found with differences in the transverse and coronal plane only.
CONCLUSIONS: These EMG pattern changes provide evidence that the immediate application of a valgus brace altered the periarticular muscle shape characteristics but not overall amplitude characteristics in those with moderate medial compartment knee OA. Changes found were not always consistent with what would be expected for an improved knee joint mechanical environment. While bracing has been shown to improve pain and function, the mechanism by which this is accomplished is still unclear, and these preliminary findings suggest a possible neuromuscular mechanism.
ACKNOWLEDGEMENT: Canadian Institutes of Health Research and Nova Scotia Health Research Foundation.

EFFECT OF MUSCULAR FATIGUE ON WEIGHT DISTRIBUTION AND MUSCLE ACTIVATION IN HEALTHY ATHLETIC INDIVIDUALS.

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AIM: The studies reporting a decrease in proprioception following a fatigue protocol suggest that muscle fatigue might diminish stability. It has in fact been shown that fatigue of the trunk or ankle muscles affects balance (Corbeil et al., 2003; Madigan et al., 2006; Mello et al., 2007; Pline et al., 2006). The purpose of this study is to evaluate the effect of lower-limb extensor fatigue on weight distribution and muscle activation during squatting in healthy male athletes.

METHODS: Five male athletes without injuries or deformations to the ankles, knees, hips or back performed squats while standing on a Matscan. Electromyographic activity of 14 lower-limb muscles was recorded using surface electrodes. During each squat, participants stopped for 0.5 second at four different positions (0^o, 30^o, 60^o, 90^o knee flexion). Three squats were performed before and three squats were performed after fatiguing the lower-limb extensors. The fatigue procedure consisted of squats performed at a frequency of 50 repetitions/minute from 0 to 60^o knee flexion with a load representing 33% of the subject's body weight on his shoulders. The fatigue protocol continued until the participant could no longer follow the rhythm. The percentage of weight on each leg was evaluated for each knee angle. The percentage of weight on the anterior and posterior parts of the feet was also evaluated. Finally, muscle activity was quantified by computing the root-mean-square value for each knee angle. Muscle activity was normalized to the values obtained while squatting at 90^o knee flexion before the fatigue procedure.

RESULTS: Preliminary results show that activity increased in both knee extensors and tibialis anterior as knee flexion increased. The increase in tibialis anterior activity at higher knee flexion suggests that weight shifts backwards as knee flexion increases. After the fatigue procedure, activity of the knee extensors increased whereas activity of the tibialis anterior decreased. The decrease in tibialis anterior activity suggests that fatigue of lower-limb extensors shifts the weight anteriorly in order to relieve knee extensors.

CONCLUSION: Our data show that fatigue of the lower-limb extensors does not only affect the activity of the lower-limb extensors but also tibialis anterior activity during squats. Our data also suggests that the modification of muscle activity may be due to a different position while squatting after the fatigue procedure.

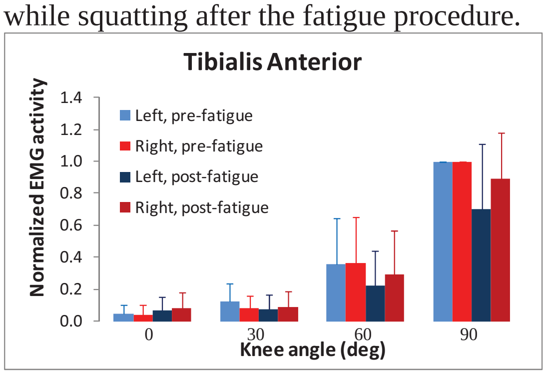

Figure 1: Normalized tibialis anterior activity pre- and post-fatigue at four different squatting

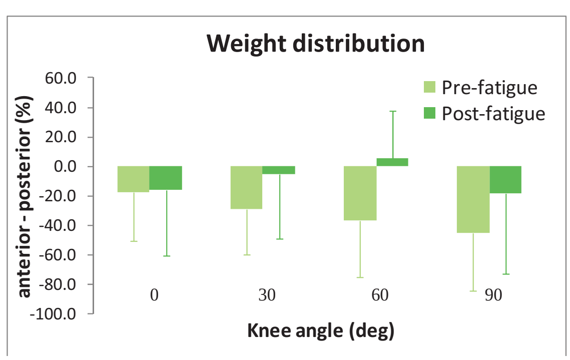

Figure 2: Difference in percentage of weight sustained by the anterior and posterior aspects of the feet pre- and post-fatigue at four different squatting positions.

STAIR WALKING TRANSITIONS ARE AN ANTICIPATION OF THE NEXT STEP

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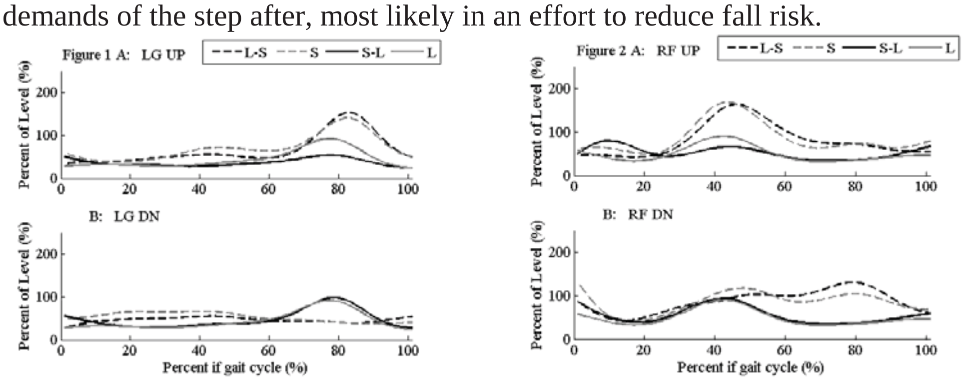
AIM: Stairs are a challenging obstacle encountered in everyday life. When individuals transition between level walking and stair walking, they must modify their leg position and forward propulsion in order to avoid falls. In a recent study, we found that the risk of falling was greater during transition steps than both level and stair walking steps (Sheehan & Gottschall, *submitted*). The purpose of the present study was to characterize the muscle activity patterns of the transition steps. We hypothesized that the activity during a transition step would be the mean of the step before and the step after. Further, this unique, and potentially variable, pattern during transition steps would indicate greater fall risk.
METHODS: Twelve, healthy college students walked on a level surface and on a portable 4-step apparatus. We collected surface electromyography data from 8 leg muscles and normalized the values for each step to the magnitude of level walking. We then compared the activity during the transition steps, level to stairs (L-S) and stairs to level (S-L), to the step before and the step after for both upstair (UP) and downstair (DN) walking. Significant differences ($p < 0.05$) were determined with paired t-tests.
RESULTS: In contrast to our hypothesis, for all transitions, the calculated mean of level and stair walking muscle activity was significantly different than the measured transition muscle activity. When we compared each percent of the gait cycle between conditions, there were 38 significant differences between the transition step and the step after compared to 67 with the step before and 59 with the mean step.
CONCLUSION: Overall, while we expected a transition step to be the mean of the step before and the step after, our data demonstrated that the transition step is more similar to the step after. We propose that this strategy minimizes fall risk in anticipation of the upcoming surface change. Interestingly, there are portions of the gait cycle where the muscle activity for the transition steps were either unique from or resembled the step after. First, during the stance phase of the UP S-L transition step, the lateral gastrocnemius (LG) activity was actually less than the activity of a level step, as if the individuals over estimated the necessary reduction in propulsion (Figure 1A). Second, during the swing phase, rectus femoris (RF) activity during all the DN conditions was essentially identical, illustrating that the function of the RF does not differ between level and stair walking (Figure 2B). In summary, our data indicate that individuals prepare for the transition to a new surface during walking by anticipating the demands of the step after, most likely in an effort to reduce fall risk.



REFERENCES: Sheehan, R.C. & Gottschall, J.S. (*submitted*) A Locomotion Index for Assessing Fall Risk during Slope and Stair Walking.

MOTOR SET IN QUIET STANDING: IS BALANCE OR POSTURE THE PRIMARY GOAL?

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AIM: Posture refers to the configuration of bodily segments. For humans the characteristic, bipedal, posture requires that the shank, thigh, torso and head segments are aligned one on top of the other. The body is unstable, so postural control requires balance, which is taken here to mean the maintenance of equilibrium and reduction of unnecessary joint moments. Because human standing requires that both balance and posture are controlled it is difficult to decide which goal has priority in the postural, motor set: is it maintenance of configuration (posture)? Is it the reduction of unnecessary joint moments (balance)? By placing the goals of posture and balance in conflict, we aim to assess which goal has the priority.
METHODS: Six healthy participants stood quietly and symmetrically on a forceplate while holding a metal bar in both hands. Participants were instructed to stand with arms hanging down, then slowly raise the bar vertically to shoulder level, then slowly move the bar horizontally forwards to the maximum extent, then hold the bar in the forward position. To minimize acceleration forces and ensure that conditions appropriate to static analysis applied throughout, each stage was timed to last 10s. Segmental motion was recorded using Vicon with a full body marker set. Inverted pendulum static analysis shows that if the primary goal was to minimize unnecessary joint moments, then during forward movement of the bar, the body should move backwards to keep the combined centre of mass of the body and bar in its initial position close to the ankle joint. If the primary goal was to maintain postural leg-trunk configuration, the leg and trunk positions would remain constant and the combined centre of mass would move forwards. Using non-parametric statistics on account of the normality test, we tested for and report the change in centre of mass position, leg segment angle, trunk segment angle, hip joint angle, and length of the torso from the 7^{th} cervical vertebra to the back of the pelvis.
RESULTS: At the 95% significance level there were significant changes in the centre of gravity position, the length of the back, and the angle of the trunk segment. The most significant change was a forward movement of the centre of gravity (25±17 mm, mean±s.d.), then shortening of the back (3±3 mm), and backward inclination of the torso (3±2 degs). Changes in leg segment angle and hip joint ankle did not reach 95% confidence levels. Observation of markers along the spine showed that shortening of the back and backward inclination of the torso was associated with increased lumber lordosis.
CONCLUSION: Posture, not balance was the primary goal. Ranking the changes in order of significance, the consistent forward movement of the centre of mass at the top and lack of consistent movement of the legs at the bottom, supports the hypothesis that leg configuration is prioritized and maintained over minimization of ankle joint moment. It seems the legs were rigidified, constraining bodily adjustment to occur at the trunk with consequent shortening of the spine and increased lumber lordosis. The general implication is that postural constraints embodied in the motor set can lead to sub-optimal coordination. Prioritization of posture over economical balance, can lead to unnecessarily high joint moments and place parts of the body (e.g. lower back) under unnecessary strain.

INFLUENCE OF THE SCALE FUNCTION ON THE WAVELETS TRANSFORMATION OF THE SURFACE ELECTROMYOGRAPHIC SIGNAL

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AIM: The recent use of wavelets transformation (WT) of EMG signal allows an accurate analysis in frequency and time domains, but suffers from standard across EMG studies. The objective of this study is to compare two procedures of WT of EMG signal, to determine the influence of scale function on surface EMG variables.
METHODS: The both WTs were made from a MATLAB® toolbox[1] (MathWorks Inc., Natick, USA). One WT was computed following a second degree polynomial scale function[2] (WT_{poly}) and the other following an exponential scale function[1] (WT_{exp}). The EMG signal was recorded from the deltoideus pars clavicularis muscle in eighty fencing attacks[3]. For each type of WT, one mean frequency (MNF) was calculated from the wavelet spectrum and the second from the reconstructed wavelet spectrum by cubic spline interpolation. These MNFs were compared with the MNF calculated from a FFT. Also, the total intensity (tp) for each type of WT was compared to the RMS value. The Pearson correlation test was used to objectify the similarity between the RMS and tp curves.
RESULTS: The MNF distributions showed significant differences ($P<0.05$) among the EMG processes (Figure 1a). The similarity between the tp and the RMS is reflected by a high correlation coefficient and was significant for the two types of WT (ranging from $r=0.59$ to $r=0.96$). The distributions of correlation coefficients showed that tp from WT_{poly} had a significantly higher correlation with the RMS than from WT_{exp} (Figure 1b).
CONCLUSION: The use of different sets of wavelets can induce significant differences on EMG variables, in both time and frequency domains. The surge of centres frequency of the last wavelets can induce an overestimation of the frequency component of the EMG signal when using the exponential scale function, in comparison with the polynomial scale function which better fit the power spectrum. Thus, the standard proposed by von Tscharner (2000)[1] are more appropriate for EMG signal processing.

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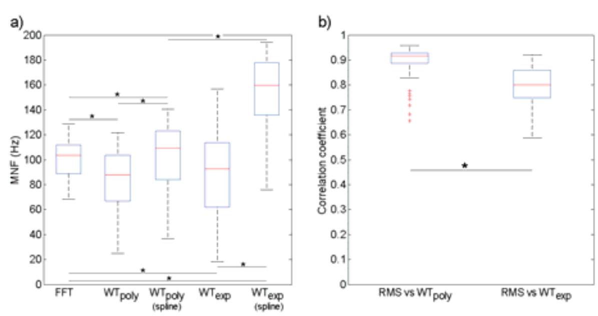

Figure 1: a) Distributions of MNFs; b) Distributions of correlation coefficients

RANGE OF MOTION IN THE UPPER AND LOWER CERVICAL SPINE IN PEOPLE WITH CHRONIC NECK PAIN

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AIM: Several studies have reported reduced cervical range of motion (ROM) in people with neck pain. Different methodologies have been used, but with a few exception they measure only head-trunk relationship and do not discriminate between upper and lower cervical motion. Recent strategies for treatment of neck pain condition include retraining the function of the deep cervical flexors that act in cranio-cervical movements. Thus objective measures of cervical ROM in flexion-extension that includes determination of cervical level can be valuable for treatment evaluation.

The aim of the present study was to compare cervical flexion and extension, separate for upper and lower cervical levels, between people with chronic neck pain and controls. Also, the association between upper and lower cervical ROM and self rated characteristics was studied.

METHODS: In a cross-sectional study design, 135 subjects (non-traumatic neck pain: n = 102, controls: n = 33) performed three trials of maximum active cervical flexion and extension. Subjects were seated in a chair with belts crossed over the chest. An electromagnetic tracker system was used to register the kinematics to construct a three-segment model including the trunk, cervical spine and head. The angle for the upper cervical level was defined as the angle between the head and the cervical spine segments. The angle for the lower cervical level was defined as the angle between the cervical spine and the trunk segments. Pressure pain thresholds, pain ratings as well as self ratings of functioning and physical activity were assessed.

RESULTS: Total ROM was reduced in the neck pain group for both the lower (controls: mean = 26.5, SD=6.7, neck pain: mean=19.0, SD =6.5 degrees) and the upper cervical levels (controls: mean = 84.7, SD = 7.9, neck pain: mean = 73.0, SD = 11.2 degrees). This reduction was direction specific: in the upper cervical level only extension was reduced and in the lower cervical level the reduction was predominately in flexion. Multivariate regression analysis revealed that lower level of physical activity, greater impairments of physical functioning, self reported problems with head movements and lower pressure pain thresholds were related to a greater reduction in ROM in the neck pain group.

CONCLUSION: Reduction of ROM is present for both the upper and lower levels of the cervical spine in people with non-traumatic neck pain. For the upper cervical level this reduction is direction specific so that only extension is reduced. The limited extension range of the upper cervical spine in the neck pain group could reflect a habituated sitting posture that includes a more extended upper cervical spine. Alternatively it could reflect an impaired functioning of the deep cervical flexors. For the lower cervical level the reduction was mainly limited to flexion. This could be a reflection of a ‘head forward posture’ that has previously been reported in people with neck pain. The associations between self rated characteristics and range of motion variables supports the validity of this methodology in research on neck pain conditions.

MULTI-UNIT ANALYSIS OF RECRUITMENT AND FIRING RATE MODULATION DURING RAMP AND STEADY CONTRACTIONS

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AIM: Recruitment and firing rate are both thought to be modulated by the same descending drive to the motoneuron pool. We examined the relationship between the recruitment profiles and firing rates of groups of motor units (MUs) during increasing and steady contractions.
METHODS: EMG signals were recorded from the brachioradialis muscle of 10 healthy subjects (5 males, ages 22-41) using three fine-wire electrodes. Trains of MUAPs were identified using EMG decomposition. Only MUs that were confidently identified in all contractions were included in the analysis (21 to 44 per subject). Recruitment was quantified by counting the number of MUs that were active at each instant in time.
RESULTS: During the ramps, recruitment increased in a roughly linear, monotonic fashion, but firing rates did not. The MUs exhibited two different types of firing behavior. In some subjects, most MUs began firing at a low rate (< 7 pps), increased over the course of about 2 seconds to a "preferred" rate, and then increased much less rapidly (Fig. 1A, left). In other subjects, most MUs began firing at the preferred rate immediately upon recruitment or after an initial doublet and then exhibited large fluctuations (Fig. 1A, right). Firing rates were similar at the same levels of recruitment during the ramps and during the steady contractions for some subjects (Fig. 1C, left), but were higher during the ramps for others (Fig. 1C, right).
CONCLUSIONS: These results suggest that recruitment follows the descending drive in a simple monotonic fashion, but that the relationship between drive and firing rate is more complicated, presumably because of intrinsic motoneuron properties.

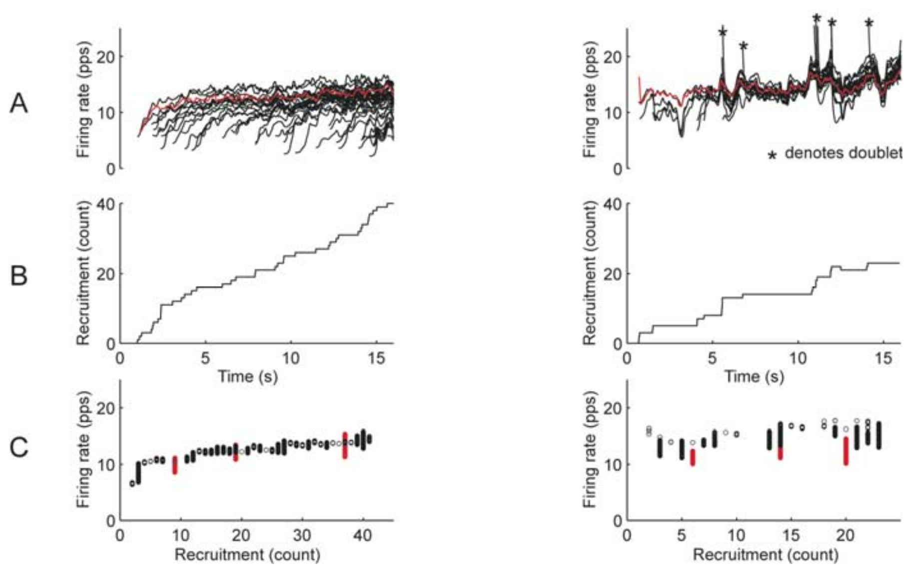

Figure 1: Firing-rates (A) and recruitment profiles (B) of two subjects. The firing rates of one MU from each subject (A, red) are plotted in (C) as a function of recruitment level during the ramp (black) and during three steady contractions of different strengths (red).

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ANKLE MOTOR FUNCTION IN CHILDREN WITH CEREBRAL PALSY

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AIM: To examine ankle motor function in terms of muscle strength, reaction time, and torque steadiness in children with and without cerebral palsy (CP).
METHODS: 14 children with CP (10.9 yrs) and 18 healthy children (CON) (12.8 yrs) participated. Inclusion criteria for the Cp group were equinus gait and no surgery within the last two years. The subjects sat on a chair with the foot placed in an ankle device connected to a Darcus strain-gauge dynamometer, while they performed isometric ankle plantar- and dorsal flexions. Hip, knee, and ankle angles were 90º, 150º and 110º, respectively. Exerted ankle torque and surface EMG in the tibialis anterior, gastrocnemius, and soleus muscles were measured. The subjects performed maximal contractions (MVC), fast submaximal contractions after a visual cue, and attempted steady submaximal contractions at 0.1 and 0.3 Nm/kg bodyweight in 12-s trials (1). Muscle strength was calculated as best of tree trials. Reaction time was calculated from trigger artifact to the time where the torque deviated 3 SD from baseline. Electromechanical delay (EMD) was calculated as the time latency between EMG onset (+/- 3 SD) to torque onset (+3 SD). Submaximal torque steadiness (T_{CV}) was calculated as coefficient of variation of the torque fluctuations (mean of 5 trials).
RESULTS: During the fast contractions, significantly longer reaction times were found for CP compared to CON (dorsal flexion: 540 vs. 437 ms, plantar flexion: 513 vs. 441 ms). Likewise, EMD was longer for CP (69 ms) than for ctrl (48 ms). During the fast submaksimal dorsal flexions, six children with CP performed unintended plantar flexion prior to the dorsal flexion (20 contractions). No contractions with unintended countermovement were seen for CON. When contractions with unintended countermovements were removed from the CP data, no significant between-group difference in mean EMD was found (53 vs. 48 ms, respectively), indicating lack of difference in the muscular component of the reaction time. Furthermore, CP showed a tendency to activate other muscles than the intended prime-mover more frequently during fast submaximal plantar flexions than CON. Muscle strength was reduced in CP compared to CON (dorsal flexion: 8.3 vs. 23.0 Nm, plantar flexion: 27.2 vs. 51.5 Nm). Furthermore, the CP showed reduced dorsal flexion T_{CV} compared with CON, and a similar tendency was seen during plantar flexion ($p = 0.072$). Moderate correlations between reaction time and T_{CV} ($r = 0.538$) were found in CON and in the two groups pooled (fast reaction related to steadier torque). In CON, the MVC was significantly correlated with T_{CV} ($r = 0.651$). Thus greater muscle strength is related to steadier torque production.
CONCLUSION: Children with CP have reduced muscle strength, prolonged reaction time, and impaired torque steadiness of isometric dorsal and plantar flexions compared to healthy children. Children with CP showed abnormal muscle activation during plantar flexion, and a CP subgroup showed unintended plantar flexion before the intended dorsal flexion. The unintended planter flexion may be a stretch reflex initiated by myofascial force transmission to the antagonist muscles (2).
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ON THE CENTRAL CONTRIBUTION TO CONTRACTIONS EVOKED BY NEUROMUSCULAR ELECTRICAL STIMULATION.

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AIM: It is well-established that neuromuscular electrical stimulation (NMES) generates contractions by the repetitive activation of motor axons beneath the stimulating electrodes (a "peripheral" mechanism). Such contractions develop due to the summation of muscle twitches associated with successive M-waves. What is not as well-established is the extent to which the concomitant activation of sensory axons contributes to NMES-evoked contractions via signals travelling along pathways through the central nervous system (CNS; a "central" mechanism). Review the evidence for a central contribution to contractions evoked by NMES. Describe the influence of NMES parameters (pulse width, frequency, intensity) on the central contribution to electrically-evoked contractions. Discuss the implications of the central contribution for rehabilitation after injury or disease.

METHODS: NMES was applied through the skin over a peripheral nerve or muscle belly. A central contribution was established by comparing contractions evoked before and during a complete anaesthetic block of the nerve proximal to the stimulation site; contractions evoked during the block can only arise from the peripheral mechanism. The central contribution was further assessed by quantifying electromyographic (EMG) activity recorded during NMES. NMES was delivered over a range of pulse widths, frequencies and intensities to explore how the central contribution depends on NMES parameters.

RESULTS: When NMES was delivered using relatively wide-pulse widths (1 ms) and high frequencies (>80 Hz) the torque generated often gradually increased throughout the stimulation and remained elevated even when the frequency was reduced (to 20 Hz). In the ankle musculature the increase in torque reached up to ~40% of that produced during a maximal voluntary contraction. The increased torque did not develop when the nerve was blocked for NMES-evoked contractions of the triceps surae, tibialis anterior and flexor pollicis longus. EMG activity recorded during 20 Hz NMES showed that motor units were recruited in three ways: 1) "time-locked" to each stimulus pulse as M-waves, 2) "time-locked" to each stimulus pulse as H-reflexes, and 3) asynchronous from each stimulus pulse with discharge frequencies that were relatively independent of stimulation frequency. Contractions evoked in muscles paralysed by spinal cord injury or stroke also showed evidence of a CNS contribution.

CONCLUSION: Large contractions can develop due to transmission along reflex pathways through the spinal cord when NMES is applied over a peripheral nerve or muscle. This central contribution is optimized when NMES is delivered using relatively wide–pulse widths, high frequencies and low intensities. The central contribution may depend at least in part on post-tetanic potentiation of neurotransmitter release from afferent terminals and the activation of persistent inward currents in spinal neurons. Enhancing this central contribution may prove to be beneficial for rehabilitation as synaptic activation recruits motor units according to Henneman's size principle and thus may generate contractions that are more fatigue resistant and help offset muscle atrophy that stems from disuse.

ASSESSMENT OF UNILATERAL CONTROL OF FORCE IN MASTICATORY MUSCLES

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AIM: Clinical conditions affecting the cranio-mandibular area could impair the mandible motor control. Pain associated with temporomandibular disorders impairs jaw motor functions like maximal clenching and mastication. The present study aims to validate a feedback based system designed to analyze the ability to control the bite force.
METHODS: 13 healthy subjects (7 females, 6 males; age range 24 to 40 yr), participated in this study. The precision of unilateral bite force control was assessed by a sensor device, built housing a flexible force transducer in a plastic structure, that was positioned in between the first molars teeth. The subject was visually presented with a sequence of different target force levels (10 to 70 % of MVC) (gray line in Fig. 1). The subject was instructed to regulate his jaw-closing force, indicated by the position of a cursor, so as to reach and match as precisely as possible a sequence of 5 different force levels (10-20-30-50-70 % MVC) displayed on a PC monitor (see figure). The experimental session comprised 3 repetitions of the task, on the left and on the right side and was performed twice in two different days. Two target matching errors were used to measure the subject's performance: mean cursor-target distance (Mean Distance MD), and the distance between the mean cursor position and the target (Offset Error (OE). All of them are also evaluated in relative terms, i.e., normalized according to the target force level and expressed in percentage.
RESULTS: The matching errors increased with increasing force level and were thus expressed as percent of the target level. A slight improvement was observed in the second as compared to the first session: MD decreased from 10.1±3.3 % to 8.1±2.6 % ($P<0.01$) and OE: from 6.2±3.2 % to 4.8±2.9 %. The two indices were highly correlated ($r=0.92$, $P<0.01$)
The method exhibited good reliability for all indices as indicated by the ICC evaluated in the first session (MD:74%; OE:76%) and between first and second session (MD:60%; OE:80%). A good correlation and no significant difference was observed between the individual performance of the two sides $r=0.85, p<0.01$.
CONCLUSION: A new method was presented which provides a quantitative evaluation of the ability to control unilateral force at the jaw. The normalization of the matching errors to the force level allows for the inter and intra-subject comparison of performance. Almost every subject presented a similar performance by the two sides. In conclusion the device seems appropriate to rate the individual performance in healthy subjects and could be potentially employed in the functional investigation of TMD patients, supporting the diagnostic and therapeutic process.

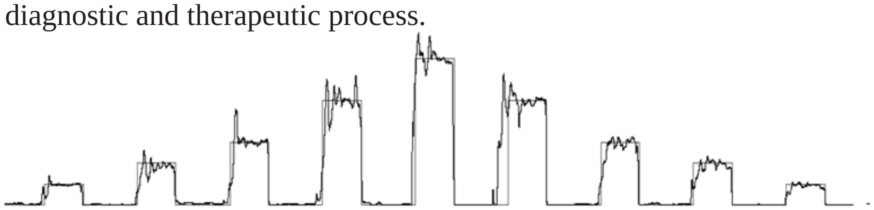

Figure 1: Example of exercise; the black line represents the target levels, the gray line corresponds to the force exerted by the subject. Calibration bars: Force: 70%MVC, time: 10 s

BEHAVIOR ANALYSIS OF THE BALANCE AND SURFACE ELECTROMYOGRAPHY DURING TRAINING OF THE CLASSIC BALLET IN THE ELEVÉ MOVEMENT WITH DIFFERENT FOOTWEAR

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AIM: The movement to raise involves the support of body weight and run with different placements of the feet by constant use of different sequences of movements of ballet and the complexity of implementation with respect to the control of loading and postural instability. Thus, this research aimed to look through the platform of postural balance and surface electromyography during movement increases achieved during the training of dancers with two different types of shoes. This study was approved by the Research Ethics Committee.
METHODS: We analyzed 10 dancers, female (19.6 years, weight 54 kg and height of 1.63 m) which had no bone injury-mioarticular in the last three months. It is emphasized that all participants are part of ballet training, with experience of at least four years and weekly training for six to eight hours. The assessment of variables through postural CoP, AP, ML, FM and TA electromyography of muscles, GL and FL were in locations where environmental conditions were favorable for the evaluation. Data were collected in two stages using two models of shoes A and B. Were taken due care with the lighting and noise sonorous as the attention of the volunteer is considered a factor that interferes with the assessment of postural control. For analysis of the dynamic and temporal parameters, we used a platform of balance and jump model BIOMEC400 (EMG SYSTEM do BRASIL Ltda) with dimensions 50 x 50 cm, with isolated signal conditioners for strain gauge, amplifier gain calibrated by software , Common mode rejection of> 100 dB, 16 bits of resolution, sampling frequency of 100 Hz , synchronized to the system model EMG800C surface electromyography (EMG SYSTEM BRASIL Ltda) previously calibrated. All dancers who participated in the study have a good time to practice, between 5 and 8 years, all practicing in soil of wood and use the same tip for a large number of classes / tests (12 or more classes / tests on each pair of shoes). Most made the choice of shoe for item "comfort", although these do not have a clear criterion for that item.
RESULTS: We find that the shoe B with the balance through the CoP, AP, ML and FM was more stable than the shoe A. We found that with the use of the shoe had a higher recruitment of muscle muscles TA, FL and GL (P <0.05, Mann-Witney test) compared the use of shoe B.
CONCLUSION: The biomechanical studies of the characteristics of dance in tips must be considered as the parameters of soil reaction forces (FRG), levels of muscle activity (EMG), distribution of pressure in the plant of the feet and kinematics for a more comprehensive study during the investigation of parameters to choose the most appropriate shoe for the practice of ballet.

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CO-CONTRACTION AND LENGTHENING VELOCITY ANALYSIS: A CASE REPORT

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AIM: In patients with cerebral palsy (CP) one of the most common and troublesome complications is spasticity. in this case report our goal is to get a deeper insight into the muscle function using simulation processes to determinate the tendon-muscle length, lengthening velocity and SEMG antagonist co-contraction. this way we can determinate feasibility of which muscle are more affected by spasticity and gain a better treatment decision for patients.
METHODS: The patient was a 7 years old female with diagnostic of CP type spastic diplegia. The patient went under a clinical gait analysis (Motion analysis Corp. MoCap System, Delsys Myomonitor IV SEMG) at three different speeds (slow, normal, and fast), all speeds were determinate by the comfort of the patient. A single stride for each leg was analyzed, collected data was processed in OpenSim 1.9.1 to determinate the normalized muscle length velocity, and with a custom procedure to determinate the stride percentage of co-contraction.
RESULTS: The analyzed data shows an increment of the lengthening velocity of *Biceps Femoris* (BF) and *Semitendinosus* (ST) from both legs in slow walk velocity to normal, but from normal to fast the muscles differs with an increment of both BF lengthening velocity and a decrement for both ST, both muscles of the right leg shows a significantly slower lengthening velocity than the same muscles from the left leg (fig.1).
In the sEMG of the same muscles the co-contraction analysis realized against the *Rectus Femoris* of the side analyzed, shows for right BF a 60% of co-contraction of the cycle, for the left BF shows a 54% of co-contraction of the cycle, for the right ST shows a 63% of co-contraction of the cycle, for left ST shows a 35%, all this results were significantly higher than the normal of 25% of co-contraction in a stride cycle.
CONCLUSION: sEMG shows an altered pattern for all muscles but doesn't allow us to determinate clearly which muscles are more affected by spasticity. On the other hand, the complementary analysis using models for simulation can give us a deeper insight into muscle function allowing the identification of more spastic muscles based on the peak velocities achieved, this because the spasticity is a velocity dependent condition.

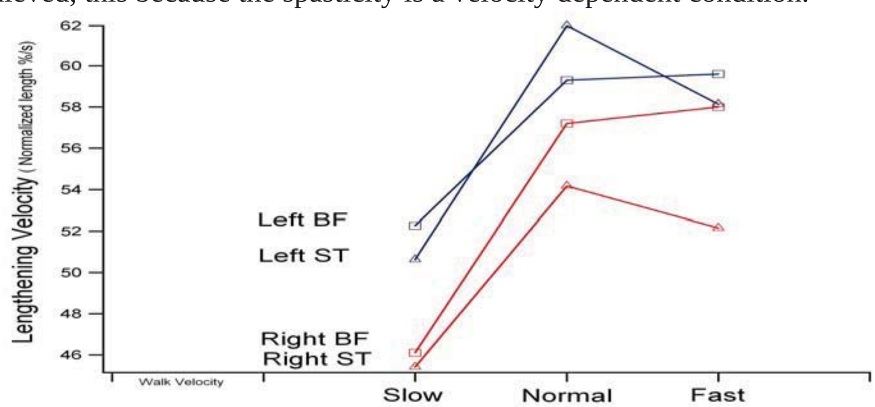

Figure 1: Peak Lengthening Velocities at different walking speeds.

SHOULDER MUSCLE RESPONSE TO GRIPPING AND BICEPS EFFORTS DURING SUBMAXIMAL SHOULDER EXERTIONS

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AIM: Gripping during shoulder exertions often leads to decreased deltoid activity and increased rotator cuff activity, as been shown with surface EMG. This could lead to overload and increased risk of injury in the rotator cuff, however, the mechanism by which this redistribution of activity occurs is not clear. Given that the long head of biceps crosses both the elbow and shoulder joints, it may transfer loads from the forearm to the shoulder. The purpose of this study was to investigate the effects of voluntary biceps contractions and hand gripping on rotator cuff muscle activity during static and dynamic exertions of the shoulder.
METHODS: Thirty-six static and 12 dynamic shoulder exertions were performed. Static exertions were performed at 30°, 60° and 90° of elevation in both sagittal (flexion) and scapular (abduction) planes using neutral and supinated forearm postures. A 40% isometric shoulder exertion was performed alone or in conjunction with either a 30% maximal grip effort or a 30% MVE biceps effort using visual feedback. Dynamic exertions were performed at 30°/s in both flexion and scapular planes with the same conditions as the static trials (neutral and supine forearm postures with i. no hand load, ii. 30% grip, iii. 30% biceps contraction). Surface EMG was collected from the anterior (AD), medial (MD) and posterior (PD) deltoids, trapezius (TR), long head biceps (BI) and long head triceps (TRI), while fine wire electrodes were used for the supraspinatus (SUP) and infraspinatus (INF) muscles (Bortec Biomedical Ltd., AB, Canada). All signals were sampled at 4000 Hz. All EMG signals were linear enveloped at 3 Hz and normalized to maximum voluntary excitation (MVE). Descriptive statistics of EMG, grip force and shoulder moment data were calculated from a 5 s window of the static exertion trials and at 30°, 60° and 90° for dynamic trials.
RESULTS: Preliminary results indicate that in flexion AD predominated torque production, ranging from 39.8 - 82.5 % MVE while MD and PD ranged from 21.4- 57.5% MVE and 15.2 - 38.7% MVE, respectively. In flexion, deltoid activity levels were relatively unchanged by the addition of grip or biceps load conditions. In the scapular plane activity was more evenly distributed across all three deltoid heads as AD ranged from 38.0 - 75.8 % MVE, MD ranging from 37.2 - 67.8% MVE and PD from 30.6 - 69.3 % MVE. Only in this plane with neutral forearm posture did deltoids respond to the load conditions. In this posture, gripping lowered MD activity by up to 14.1 % MVE and PD by up to17.2 % MVE, while adding a biceps exertion decreased activity by up to 14.1 % MVE (MD) and 9.3% MVE (PD). In the scapular plane INF activity decreased by up to 12.7% MVE during gripping trials and by up to 9.7% MVE during biceps exertions when compared to the no load condition. As expected, forearm supination led to greater biceps activity by about 15% MVE in flexion and 25% in scapular plane, during the gripping and no hand load trials.
CONCLUSION: The coordination of the shoulder complex varied depending on the plane of action, forearm posture, and in the scapular plane, the load condition. Initial results suggest that the scapular plane may allow for more effective recruitment of all heads of deltoid, potentially stabilizing the joint. Further examination of the fine wire EMG from the rotator cuff muscles will provide insight into the complex coordination required at the shoulder. Further analysis of the dynamic trials in addition to the current data will provide detailed input for use in a biomechanical simulation to examine individual muscle contributions to external shoulder moments under various constraints.
ACKNOWLEDGEMENT: NSERC (Canada) Discovery Grant #217382 (PJK).

POSTURAL CONTROL VARIABILITY AND ELECTROMYOGRAPHY ANALYSIS DURING TRAINING OF THE CLASSIC BALLET

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AIM: The movement to Elevè involves the support of body weight and run with different placements of the feet. The constant use of various sequences of movements of ballet and the complexity of implementation with respect to the control of loading and postural instability, this movement was selected for this research study with the objective of the analysis through the platform of postural balance and surface electromyography during amounts of movement made during the training of dancers with two different types of shoes

METHODS: This study was approved by the Research Ethics Committee. We analyzed 10 dancers, female (19.6 years, weight 54 kg and height of 1.63 m) which had no bone injury mioarticular-the last three months. It is emphasized that all participants are part of the corps de ballet of the city, with experience of at least four years and weekly training for six to eight hours. The assessment was made in a posture where environmental conditions were suitable for evaluation. Data were collected in two stages using two models of shoes A and B. Were taken due care with the lighting and noise sonorous as the attention of the volunteer is considered a factor that interferes with the assessment of postural control. For analysis of the dynamic and temporal parameters, was used a balance platform model BIOMEC-400 by EMG System do Brasil Ltda , with dimensions 50 x 50 cm, with isolated signal conditioning for strain gauge, amplifier gain calibrated by software , Common mode rejection of> 100 dB, 16 bits of resolution, sampling frequency of 100 Hz synchronized with surface electromyography model EMG800C by EMG System do Brasil Ltda previously calibrated

RESULTS: All dancers who participated in the study have a good time to practice, between 5 and 8 years, all practicing in soil of wood and use the same tip for a large number of classes / tests (12 or more classes / trials with each pair of shoes). Most made the choice of shoe for item "comfort", although these do not have a clear criterion for that item. We found that the shoes B postural balance was more stable than the shoe A. We found that with the use of the shoe had a greater muscle recruitment compared the use of shoe

CONCLUSION: The study of biomechanical characteristics of the dance on the tips should consider parameters such as forces of reaction of the soil, levels of muscular activity, distribution of pressure in the plant of the feet and kinematics for a more comprehensive study for the investigation of parameters that can mitigate the possible damage caused during the practice of dance.

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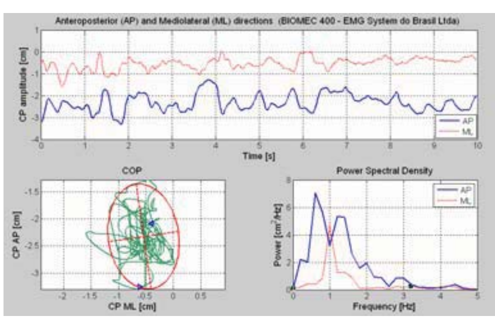

Figure 1: Variables of postural balance with shoes A.

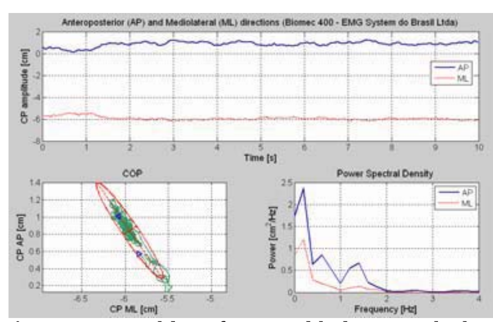

Figure 2: Variables of postural balance with shoes B

SPATIAL INFORMATION IN MULTI-ELECTRODE DATA FOR MYOPROSTHESES

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AIM: Spatial statistical properties of multidimensional electromyographic (sEMG) signals for control of multifunctional myoprostheses are studied by an information-theoretic approach.
METHODS: In order to assess the informational content of signals available for the control of a transradial hand prostheses we recorded 126 monopolar sEMG signals from an electrode array, see Fig. 1a. For each electrode *i* the entropy M_{ii} (Fig. 1b) and the mutual information M_{ij} between the signals from electrode *i* and all other electrodes *j* were calculated. The spatial configuration of the mutual information w.r.t. *i* can be well approximated by a least-square exponential fit function with radial length scale z_i (see Fig. 1c). Similarly, an field of length scales w_i was derived from the correlation C_{ij} (not shown). Both z_i and w_i serve as a measure of the local spatial redundancy of the myographic signals, where large values imply high redundancy. The data were obtained from an able bodied subject performing repeatedly eight different static contractions (hand open and close, wrist flexion, extension, abduction, adduction, pronation and supination) which allowed us to calculate redundancy fields z_i and w_i for each condition. The relative specificity of the signals at an electrode is then obtained as the ratio of condition-dependent and condition-independent length scales. For classification electrodes can be selected for each condition from those with a high specificity value. The patterns M_{ij} and C_{ij} were also directly used as features for the classification of the movements based on the data by a support vector machine (SVM).
RESULTS: While the correlation of myographic signals between electrodes generally extends over large spatial ranges, the mutual information varies strongly across electrodes. For some behavioral conditions the signals show larger dependencies than for others. This indicates highly specific response characteristics of single electrodes within the multidimensional electrode array. Consequently, the classification accuracy of the movements based on the M_{ij} values was nearly perfect (two errors among 320 samples) for time intervals of 100ms, a rate which could not be reached using the C_{ij}.
CONCLUSION: This study is part of an exploratory data analysis for the optimization of the spatial position and the number of electrodes at increased complexity of the set of executable prosthesis movements. Although myoelectric activity for particular movements typically extends across many electrodes, movements can be identified for most of the pairs of electrodes that cause statistically independent activations even at small electrode distances. Comparison of mutual information and correlation shows that the higher-order statistics contributes to the spatial variability of the signals and can be efficiently used in order to improve the classification of the myosignals for control.
ACKNOWLEDGEMENT: We thank W. Paulus (Göttingen University) for providing us with a Biosignal amplifier for this study. The project is supported by grant #01GQ0811 within the National Bernstein Network Computational Neuroscience.

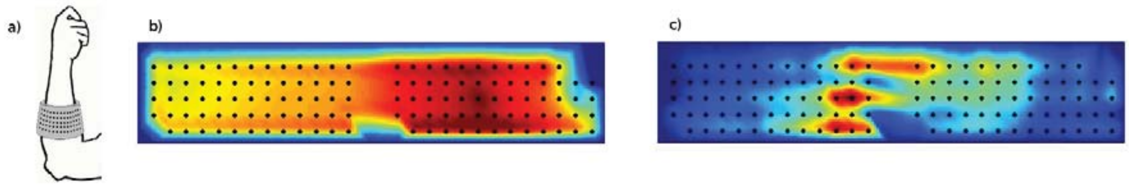

Figure 1: a) Location of the electrode array on the forearm of the participant. b) Entropy for condition "wrist flexion" at a scale from 1 (blue) to 3 (red). c) Informational length scale minimized over conditions at a scale from 0.6 (blue) to 2 (red), with blue regions indicating the relevance of single electrode signals.

THE BRUXMETER: A PORTABLE SEMG DEVICE FOR MONITORING THE MASSETER ACTIVITY AND THE HEART FREQUENCY IN A NATURAL ENVIRONMENT

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AIM: The aim of the study was to develop a portable sEMG device in order to facilitate the diagnosis of bruxism in a more confortable and less expensive way for both the patient and the clinician. Since it is well known that the bruxism activity is related with an alteration of the heart frequency, the device was developed to record both myoelectric signal from the superficial masseter of each side and myoelectric signal from the heart.
METHODS: The study was performed on the masseter muscle of both sides of ten healthy volunteers and fifteen bruxers according to the minimum criteria of the American Academy of Sleep Medicine). The sEMG signals were recorded with a bipolar concentric electrode (Code®, Spes Medica, Battipaglia, Italy) in order to permit an easy application of the electrode by each patient and avoiding any electrode orientation problem: this electrode is the only sensor purely isotropic, that is invariant to rotations. Derived signals from the heart were obtained with two monopolar electrodes located on the clavicular region of both sides. Myoelectric activities were recorded by each subject at home in one night during sleep (at least 4 hours of sleep), after an appropriate training regarding the use of the device. Myoelectric signal were stored on a micro-SD card and then analysed with an original software (OT Biolab®, OT Bioelettronica, Torino, Italy).
RESULTS: A total of 25 nights were recorded. Only three nights were excluded due to 1) premature removal of the device, 2) battery failure, 3) electrodes' noise. Results showed that 1) bruxers present a higher number of masseter contractions per night, 2) bruxers present alteration of the heart frequency associated with some masseter contractions, 3) this characteristic permit the identification of those contractions that are expression of bruxism activity according to the existing literature, 4) this identification support a more precise diagnosis of bruxism with respect to other portable EMG device that do not record the heart activity.
CONCLUSION: These preliminary findings suggest that the Bruxmeter is able to distinguish between bruxers and non-bruxers.

MODELLING FINGER FLEXOR TENDON EXCURSIONS AND MOMENT ARMS

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AIM: A detailed musculoskeletal model of the hand is needed to study the pathomechanics of tendon disorders and carpal tunnel syndrome. The purpose of this study was to develop a biomechanical hand model with realistic finger flexor tendon excursions and moment arms.
METHODS: Modelling software (SIMM 4.1, MusculoGraphics Inc., Santa Rosa, CA) was used to refine an existing upper extremity model (Holzbaur et al., 2005) to which movement capabilities were added for the middle, ring and little fingers. The metacarpophalangeal (MCP) linkages were modelled as universal joints while the proximal and distal interphalangeal (PIP and DIP) linkages were modelled as simple hinges. Two modelling approaches were used to adjust the flexor digitorum profundus and flexor digitorum superficialis (FDP and FDS) tendons. The control point (CP) method used control points to constrain tendon paths, providing anatomic fidelity by representing annular pulleys. The joint wrapping (JW) method used wrappings at the finger joints to constrain tendon paths, which were not anatomically realistic. Tendon paths in both CP and JW models were iteratively adjusted to match excursions and moment arms predicted by a previous regression model for a 50^{th} percentile male (Armstrong and Chaffin, 1978). To further evaluate the CP and JW models, FDP and FDS moment arms were measured for 3 participants using grey-scale sonography in a neutral hand posture. Finger segment lengths and joint thicknesses were also measured. Experimental moment arms were compared to both models. Manual scaling of model parameters (in SIMM) facilitated comparisons with the ultrasound data.
RESULTS: Tendon excursions in the CP and JW hand models were linear with MCP, PIP and DIP flexion/extension ($r^2 > 0.97$) and were similar to Armstrong and Chaffin (1978) with the JW model best matching the regression output. Average RMSDs in the JW model were between 0.04 mm (FDP5, DIP flexion/extension) and 0.63 mm (FDS2, MCP flexion/extension). Moment arms in the CP model did not agree with Armstrong and Chaffin (1978) at the MCP and PIP joints, which varied with flexion/extension compared to the constant values predicted by the anthropometric regression model. Conversely, JW moment arms were similar to Armstrong and Chaffin (1978) throughout joint motion simulations with average RMSDs between 0.08 mm (FDP5, DIP flexion/extension) and 0.83 mm (FDS2, MCP flexion/extension). While the JW model appeared to be a better match of the previous regression model, locations of the tendon paths were anatomically inaccurate. In terms of empirical measurements, FDP and FDS moment arms (from ultrasound) were positively related to MCP, PIP and DIP thicknesses (all $r^2 > 0.7$, $p<0.01$). In the JW model, scaling joint thicknesses also scaled moment arms proportionately. Furthermore, FDP and FDS moment arms measured using ultrasound at the PIP joints were similar to those generated by the JW model. Experimental moment arms were generally smaller at the MCP joint and larger at the DIP joint than the JW hand model. Since only a small sample (n = 3) was used in this study, additional research is needed to quantify finger flexor moment arms using *in vivo* methods.
CONCLUSION: The JW model best matched tendon excursion and moment arm data (compared to the CP model) even though anatomical fidelity was not preserved. Depending on user needs, both anatomic fidelity and model outcomes should be considered as compromises may be necessary in the modelling process. However, further research is needed to evaluate tendon excursions and moment arms *in vivo*.
ACKNOWLEDGEMENT: NSERC (Canada) Discovery Grant #217382.

QUANTIFYING MOTOR CONTROL OF THE KNEE DURING DIFFERENT FUNCTIONAL TESTS IN SUBJECTS WITH ACL INJURY – METHODOLOGICAL DEVELOPMENT

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AIM: The aim of this study was to investigate whether variation in the knee joint axis position is suitable as a measure of the motor control of the knee, in subjects with anterior cruciate ligament injury (ACL). The rotation axis was defined by a helical axis model (Woltring 1994, J Biomech). Two functional tests were studied; 1) Two Leg Squat, which is a standardised knee bending using both legs and 2) One Leg Hop, which is a maximal distance jump. One Leg Hop is common to use as a clinical test in ACL rehabilitation, since this jump requires explosive muscle strength, knee stability, balance and confidence in the capacity of the knee. The hypothesis was that there is a better control of the knee during the less demanding Two Leg Squat and that this should be reflected by less variability in the knee joint axis position.

METHODS: The study is a long term follow up of subjects ~20-25 years after ACL rupture and surgical reconstruction. This is an ongoing study and so far 20 subjects have been included in the analyses. Measurements were performed in a movement laboratory. Rigid clusters with reflective spherical markers were attached on shank and thigh, and movements were registered with an optical motion capture system (240 Hz). Ten repetitions of Two Leg Squat were performed, and the first three were selected for further analysis. Three repetitions of One Leg Hop, jumping with the injured leg, were then performed. The helical angle and the instantaneous helical axis were calculated for the injured knee. For each subject and repetition, two variables were derived: 1) The total range of the helical angle, as a measure of range of motion of the knee joint and 2) The condition number of the set of instantaneous axes, as a measure of the rotation axis variability (Grip et al 2007, J Clin Biomech). If the set of instantaneous axes are close to parallel (i.e. axis position is stable), the condition number is high, while a set of scattered axes (i.e. axis position varies over time), corresponds to a low condition number.

RESULTS: The condition number was significantly lower during One Leg Hop (4±1) as compared with Two Leg Squat (9±3), showing that the knee joint rotation axis was less stable during One Leg Hop ($p<0.01$, repeated measures ANOVA). The range of motion was likewise lower during One Leg Hop (51.2±14.9 deg) as compared with Two Leg Squat (97.7±22.8 deg) ($p<0.01$, repeated measures ANOVA).

CONCLUSION: The variation in axis position was larger during One Leg Hop than during Two Leg Squat, even though the range of motion of the knee was larger during Two Leg Squat. This reflects a larger stability of the knee during Two Leg Squat, and indicates that the condition number may be used to quantify motor control of the knee. However, measurements must be performed on control subjects to test this hypothesis further.

BALANCE DISORDERS IN MULTIPLE SCLEROSIS: POSTUROGRAPHIC LINEAR AND NON LINEAR DATA ANALYSIS PROSPECTS

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AIM: The perturbations of balance represent one of the main symptoms in multiple sclerosis (MS). Proprioceptive ataxia is effectively found in more than 80 % of cases after 5 years of evolution, and contributes to increase balance disturbances. The scale usually used to estimate the level of handicap in MS is expressed by the expended disability status scale (EDSS). The literature remains poor as regards the posturographic studies in MS.
METHODS: 96 MS and 90 healthy subjects paired in sex and age were included. Two recordings in open and close eyes conditions were made for each subject on a standardize force plate. Posturographic data (surface, speed, average position in x and y axis, spectrum analysis by the FFT) were compared with EDSS. We proceeded to a linear and a non linear mathematical data analysis and quite particularly the quantification of recurrences analysis (RQA).
RESULTS: Mathematical linear methods don't allow defining EDSS with precision, percentage of recurrence (non linear analysis) gave us better results. We observed on the Recurrence Quantified Analysis (RQA) curves the possibility to separate various MS populations according to their EDSS with a significant rate of correlation. The possibility of separating the populations, with the rate of recurrence was established with a correlation from 0.8. The prediction was possible with an accuracy of 0.5 on the scores from 1.5 to 45, which equals of commonly allowed skew for a specialist.
CONCLUSIONS: The RQA method and particularly the percentage of recurrence, enable us to separate the population (for EDSS> 1) using posturometric measurements. We can also estimate this score directly starting from measurements resulting from the platform. The accuracy of 0.5 is equal to the skew of an expert. Our method presents its limits, indeed, for the EDSS≤1.5 the capacities of balance regulation are not very faded. With regard to the EDSS> 5, our data base was insufficient. By this way we can establish a specific postural model of patients MS for EDSS between 1.5 and 5. This preliminary work shows the possibility for interesting prospects as regards predictions about evolutionary potential of the disease.

SELECTIVITY OF ELECTRICAL STIMULATION FOR GRASPING SUPPORT

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AIM: Electrical stimulation (ES) of arm and hand muscles is a functional tool for the support of grasp function. Sufficient stimulation of finger flexor and extensor muscles, together with the thumb musculature can support natural grasping function. Yet, it remains unclear how selectively different movements involved in grasping can be supported by means of electrical stimulation. Electrode placement is a crucial point in ES of muscles aimed at functional movements. Spatial distribution of isometric recruitment curves gives information about the best electrode location for one muscle. It is expected to find different optimal electrode locations under different isometric positions and between different subjects.
METHODS: The experiments are completed with healthy subjects. Torque responses to ES are evaluated in a custom built setup. The setup measures exerted forces for all individual fingers and the wrist in an isometric position. The wrist was restricted in several isometric positions: 0, 45 or -45 degrees of flexion/extension and 0, 90 or -90 degrees of pro/supination. Extensor Digitorum Communis (EDC), Flexor Pollicis Longus and Thenar muscle group are selected for stimulation. Firstly, the point where a torque response is evoked by minimal stimulation intensity is determined for each selected muscle. These points are defined as optimal stimulation points. For the EDC muscle several points are selected, corresponding to optimal stimulation of each finger. Secondly, a mould of a 5x5 grid is placed around each optimal point, to be able to characterize the spatial distribution of isometric recruitment curves for each muscle. Finally, an analysis is made of the variation of the spatial isometric recruitment curves in different isometric positions and different subjects.
CONCLUSION: For future designs of grasping prostheses and grasping rehabilitation devices, the variation of optimal stimulation points for different muscles must be taken into account. The results presented here, facilitate the optimization of such designs.

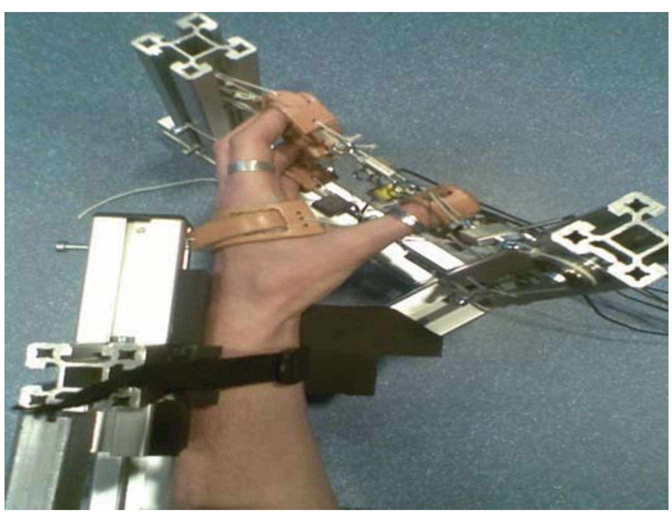

Figure 1: Top view of the custom built force measurement setup

MECHANOMYOGRAPHIC MAPPING OF THE SOLEUS

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AIM: Tissue velocity mapping of the soleus muscle shows that higher velocity regions overlay the aponeuroses connected to the Achilles tendon (Finni, 2003). The aim of this experiment was to produce a 2 dimensional mechanomyographic map of the surface response of the human soleus to an electrical stimulus and to investigate if it reveals any structural or functional information.
METHODS: This experiment was conducted on an adult male who had an array of four, 3-axis accelerometers positioned along the length of the soleus muscle. An increasing electrical stimulus was applied to the posterior tibial nerve in the popliteal fossa. The stimulation level is recorded up to Mmax where the amplitude of the EMG signal reaches a plateau. An EMG electrode was used to confirm that the stimulation level remained at Mmax.
RESULTS: The simultaneous MMG response from each of the sensors in both the parallel and lateral directions is shown in figure 1. The response shows nonuniform contraction characteristics with varied acceleration amplitudes along the length of the soleus muscle. It can be seen that the maximum acceleration is measured by the distal sensor, nearest the Achilles tendon, which is the first to respond to an electrical stimulus. The proximal sensor also demonstrates high acceleration but at opposite phases of the waveform.
CONCLUSION: The relatively low acceleration measured parallel to the muscle illustrates a short contraction in the soleus closely flowed by a larger acceleration in the lateral direction. Simultaneous recording of the response from all 4 sensors would appear to show a nonuniform rotation of the muscle as it contracts, similar to the isometric response reported (Finni, 2003). Extended studies may deduce that MMG arrays could be used as an inexpensive tool to provide *in vivo* measurements directly from the surface of the muscle to aid with the understanding of the muscle structure and function.

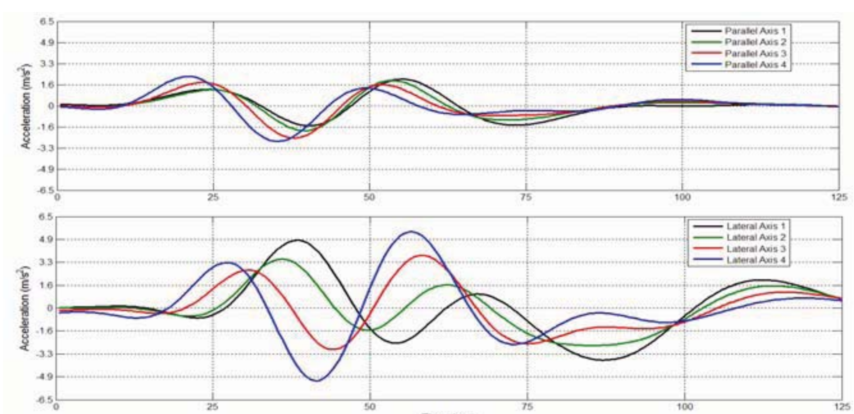

Figure 1: The MMG responses from 4 MMG sensors arranged in a line along the soleus. Sensor 1 is the proximal sensor while sensor 4 is the distal sensor (nearest the Achilles tendon).

AUTOMATIC MUSCLE ACTIVITY ONSET DETERMINATION IN COUNTERMOVEMENT JUMP

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AIM: Aim of this research was to find a method (and its parameters) that would allow for correct and automatic determination of muscle onset and offset while performing countermovement jump movements thus enabling further analysis of these movements.
METHODS: Surface electromyographic signals of leg muscles were recorded on both legs as 25 professional handball players performed countermovement jump. All jumps were synchronized in time to force platform recordings. Two algorithms for automatic onset determination were tested. First algorithm, as previously described in (Hodges and Bui, 1996), searched for a time window in which mean amplitude of the samples exceeded given amplitude threshold and considered first sample of such window as the muscle onset moment. This algorithm was then modified to remove short periods falsely detected as muscle activity by adding post processing that determined if detected activity was too short. If the detected muscle activity change resulted in activity shorter than time given as the duration threshold it was discarded as false detection. These algorithms were tested on recorded signals with different combinations of parameters (amplitude and duration threshold values, time window width) on both full wave rectified EMG signal and low pass filtered EMG signal with different cut off frequencies. Comparison with onset/offset times determined visually by an experienced researcher is pending.
CONCLUSION: Modified algorithm for detecting muscle onset showed better results while basic threshold algorithm found a large number of short activity burst periods. Due to low standard deviation of the baseline, better results were obtained using amplitude threshold defined as a percentage of maximum signal amplitude.
REFERENCES: Hodges, P. W., & Bui, B. H. (1996). A comparison of computer-based methods for the determination of onset of muscle contraction using electromyography. *Electroencephalography and clinical Neurophysiology, 101*(6) 511-519.

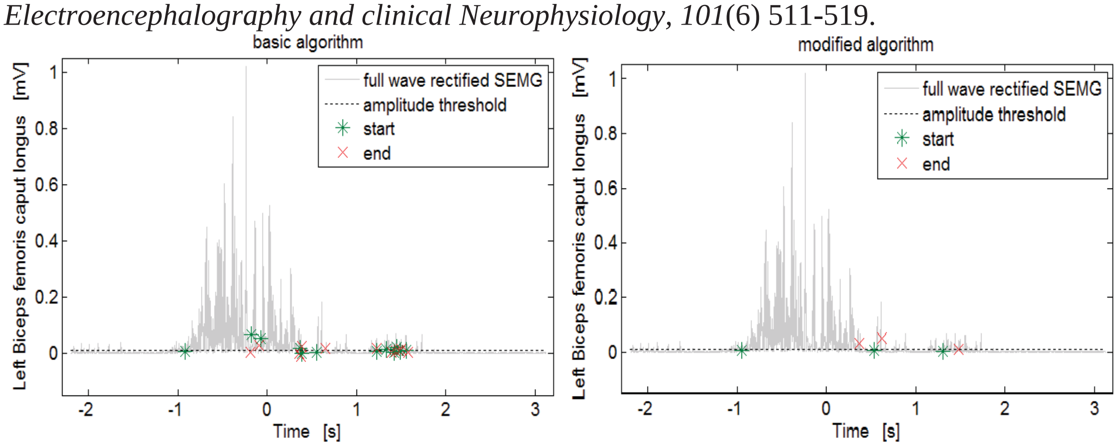

Figure 1: Comparison of detected muscle onset using basic algorithm (left) and modified algorithm (right). Algorithms shown use these parameters: window width 50 ms,amplitude threshold = baseline + 1 * std. deviation, LPF: elliptic filter *f* = 50 Hz,.Modified algorithm uses duration threshold of 50 ms (raw data are shown).

CONCENTRIC-ECCENTRIC FORCE TRANSIENTS: LINEAR & NON-LINEAR sEMG ANALYSIS

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AIM: The main purpose of this study was to examine the most important linear and non-linear parameters usually extracted from surface electromyogram (sEMG) in the course of concentric-eccentric upper limb movements. Differently from analogous works appeared in the literature on the same matter, we have paid greater attention to the different strategies the neuromuscular system would implement during the following phases of movement: *phase1)*-pure concentric; *phase 2)*-inversion from concentric to eccentric; *phase3)*-pure eccentric; *phase 4)*-inversion from eccentric to concentric. During these four phases, we have compared the changes occurred in both conduction velocity (CV) and percentage of determinism (%DET). As it is well known, these two parameters reflect the different type (I or II) of muscle fibres mainly recruited for the accomplishment of the muscle task as well as the greater or lower amount of synchronization of the active motor units (MUs) firings.
METHODS: An experimental set-up was planned for sEMG recordings of Biceps Brachii muscle in 10 normal subjects during the repetitive execution of flexion-extension exercises, while an isokinetic KinCom dynamometer imposed one of two possible constant angular velocities (10°s^{-1} and 180°s^{-1}) during a 70°÷110° range of motion. One set of repetition was carried out at the lower velocity ($task_1$) and then, after a suitable rest interval, it was followed by that at higher speed ($task_2$). After a longer recovering period, this whole sequence was repeated ($task_3$ and $task_4$). Electrode configuration chosen was a 4 electrode arrays placed over the muscle belly in order to allow the underlying muscle CV estimation with the technique described. Regarding the %DET, relative implemented algorithm, according to the RQA (Recurrence Quantification Analysis) technique, has been applied to sEMG recordings taken from the central electrode of the linear array.
RESULTS: CV and %DET values for each subject are average parameters values evaluated in homologous $tasks_i$, *i=(1.OR.3).AND.(2.OR.4)* in all homologous *phases j=1,..,4*. Therefore, individual data where averaged for all subjects. Concerning the non-linear parameter, preliminary results show a reliable reduction of %DET during phase 1 and 3 of pure concentric/eccentric action, whereas there is an evident increase during both transient phases. This results is valid for both angular velocities investigated as a consequence of the robust behaviour of this non linear parameter which is independent of stationarity/non-stationarity hypothesis. For what regards the other parameter, first of all, CV measurement was allowable only for task 1 and 3, whereas CV evaluation gave uncertain values during higher speed tasks. For these reason, the more speedy tasks cannot be considered for what concerns CV. Conversely, at 10°/sec, CV was reliably greater during eccentric exercises compared with that measured during concentric exercises. The same CV behaviour was obtained in phase 4 versus phase 2.
CONCLUSION: %DET behaviour can be explained in terms of lower MU synchronization needed by the neuromuscular control system during the accomplishment of “simpler” tasks of pure eccentric/concentric action (phase 1 and 3), whereas the corresponding increase during the transients can be explained in terms of greater muscular control, and then of higher MU synchronization. The CV behaviour can be understood if we consider that eccentric action is consistent with a preferential type II UM recruitment.

MUSCLE ACTIVITIES DURING EXERCISE WITH MODIFIED STEPPING CLIMBING MACHINE

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AIM: Exercise with stepping climbing machine is popular in fitness clubs and rehabilitation centers. Although it can assist to strengthen lower extremity muscles under lower impacts, the training only focuses on the muscle groups responsible to motions in the sagittal plane. The modified stair-climbing machine (S770, SportsArt, Taiwan) with the curved pedal trajectory was designed for assisting the exercise in frontal and sagittal planes. Therefore, the purpose of this study was to investigate effectiveness by evaluating the kinematics and muscle activities of lower extremities during stepping in different conditions.
METHODS: 12 young adults (2 female and 10 male, 24.5±1.2 y/o) without related disorders were recruited. Subjects were asked to step the stair-climbing machine at self-selected speeds in four conditions, whole pedal trajectory or comfortable stepping range with trunk kept at center or shifted with weight bearing, respectively. The Eagle digital real-time system with 8 digital cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) was used to capture the positions of reflective markers. A multi-channel EMG system (MA 300, Motion Lab Systems, Inc., Baton Rouge, LA, USA) was used to collect activities of hip abductor, hip adductor, knee flexor, and knee extensor with sampling rate at 1000Hz. The range of joint motion and muscle activities in a stride cycle, the period between two continuous highest positions of the left pedal, were analyzed by our custom software.
RESULTS: In the initial, the hip and knee flexion combined knee internal rotation. Then, hip and knee continued to extend combining with hip abduction to lower the pedal. Knee extensors (VM, VL, RF) and knee flexor (hamstring) co-contraction occurred in initial phase to maintain stability and prepare to downward the pedal, followed by activating hip abductor (gluteal medialis) and knee extensors to lower the pedal till required range. However, no obvious difference of muscle activities was found between four conditions.
CONCLUSION: Exercise with modified stair-climbing machine would activate muscle groups responsible to movements in the frontal plane. Efficient hip abductor strength is crucial for daily activities, such as walking and obstacle crossing. Therefore, the modified stair-climbing machine might be appropriate for training subjects with weak hip abductor and elderly under indication.
ACKNOWLEDGEMENT: The authors thank SportsArt Fitness for financial support.

Figure 1: Side-view of modified stair-climbing machine

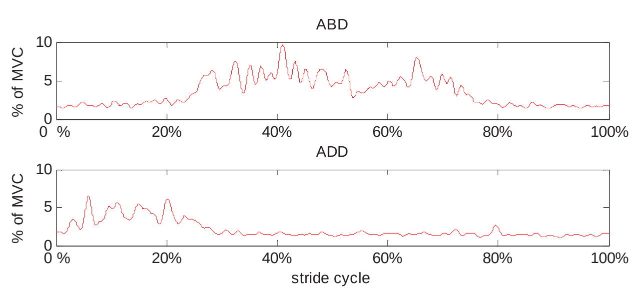

Figure 2: Activation of hip abductor and adductor in a stride cycle

DIAPHRAGM FUNCTION MONITORING IN THE LOWER ESOPHAGEAL SPHINCTER AREA

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AIM**:** The diaphragm is the major respiratory muscle. At the same time, however, its crural part has the function of external esophageal sphincter in the so-called high pressure zone (HPZ) area which is the fundamental component of the anti-reflux barrier. According to many authors, its disorder leads to gastro-esophageal reflux disease (GERD). We monitored the activity of this part of the diaphragm during maximal respiratory manoeuvres using esophageal manometry simultaneously with spirometry in patients with verified GERD.
METHODS: Examination of pressure changes in the HPZ area of the esophagus using esophageal manometry with concurrent spirometric diaphragm examination by simultaneous measurement of maximum occlusal pressures (PI max and PE max). A set of 20 patients (11 women and 9 men) aged 43.6 in average were examined. All patients had endoscopically or pH-metrically verified GERD. Change in maximal pressures in the HPZ area during maximal respiratory manoeuvres (PIm max and PE max) compared to pressure at rest in the HPZ area of the esophagus, as well as the dynamics and nature of these changes, were measured.
RESULTS: In 19 patients, significantly lowered inspiratory occlusal pressures (PI max) = p=2.77455 E -09 were found, and also expiratory pressures (PE max) were significantly lower p= 0.053830198. During PI max, the pressure in the esophagogastric junction (EGJ) increased from mean values at rest of 15mm/Hg by 415% in average to a mean of 62.47 mm/Hg (p=0.000003) and during PE max by 369% to a mean of 55.42 mm/Hg (p= 0.00001). During respiratory manoeuvres we also recorded a decrease in pressure in the HZP reaching even negative values – a mean of -14.32 mm/Hg during PI max and a mean of -13.29 mm/Hg during PE max. All the negative values are significantly lowered compared to LES base ($p<0.001$). According to the dynamics and time sequence of the pressure changes in the HPZ of the esophagus during PI max and PE max manoeuvres, the changes can be divided into 4 basic types of reaction of different nature.
CONCLUSION: The overwhelming majority of patients with GERD have decreased diaphragm function; we verified this by measuring the maximum occlusal pressures. This fact points to impaired anti-reflux barrier of which the diaphragm is a component. Despite decreased diaphragm strength, significant pressure changes are recordable in the HPZ area of the esophagus, which confirms the importance of the crural diaphragm functioning as a so-called external esophageal sphincter. During maximal respiratory manoeuvres (PI max and PE max) not only positive pressure changes, but also a significant decrease in pressure in the HPZ, reaching even significant negative values, occurred. It can be inferred from this fact that during these manoeuvres the crural diaphragm undergoes concentric (increase in pressures) as well as excentric contraction which dilates the oesophagus, leading to the decrease in pressures in the HPZ. Excentric contraction is seldom mentioned in the literature. Based on the nature of pressure changes in the HPZ we recorded 4 basic types of reactions in our subjects and we can therefore presume 4 different strategies of performing the maximal respiratory manoeuvres with differing diaphragm activity. We consider our results significant for the understanding of the importance of the diaphragm in GERD etiopathogenesis as well as for the monitoring of the activity and work of the diaphragm in general.

EFFECT OF RECOVERY TIME AFTER FATIGUE IN PATIENTS WITH CHARCOT-MARIE-TOOTH 1A (CMT 1A)

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AIM: The aim of this study was to evaluate the effect of recovery time on neuromuscular function following a fatiguing task in patients with Charcot-Marie-Tooth IA and healthy individuals.
METHODS: Eight patients with Charcot-Marie-Tooth IA (35.8±9.9 years; mean±S.D), 3 males and 5 females, Barthel>90 and Tinetti>20, were matched for age and gender with 8 healthy individuals (35.1±1.1 years) and asked to perform 3 attempts to achieve their maximal isometric voluntary contraction (MVC) of the knee extensor muscles before a fatiguing task (Pre-fatigue). They then performed a fatiguing task by maintaining 80% of MVC till exhaustion. MCV was then repeated after 15 s (1Post-fatigue) and after 10 min of recovery (2Post-fatigue). Surface EMG was measured during MVC by means of linear arrays of four electrodes placed on the vastus lateralis muscle and root mean square (RMS) and muscle fiber conduction velocity (MFCV) were obtained. Statistical comparisons between the 2 groups and the 3 conditions were carried out by two way ANOVA for repeated measures, followed by post-hoc where appropriate, with significance set at P<0.05.
RESULTS: MVC was significantly lower in patients than in controls in the pre-fatigue condition (91.9±45.9 vs 161.1±75.5 Nm, P<0.05) and there was a tendency to be lower in the other 2 conditions (1Post-fatigue 84.0±43.4 vs 147.8±77.5 Nm, P=0.062; 2Post-fatigue 86.9±47.5 vs 149.7±74.0 Nm, P=0.063). MFCV and RMS, expressed as a percentage of Pre-fatigue values (Figure 1 and 2, respectively), decreased in the 1 Post-fatigue condition in both patients and controls, but only the controls returned towards Pre-fatigue levels in the 2 Post-fatigue condition.
CONCLUSION: Patients with Charcot-Marie-Tooth IA were weaker than the healthy controls in the force exerted by their knee extensor muscles, which is likely to be attributed to the neuromuscular disease. Moreover, patients were not able to fully activate the fatigued muscles after a long lasting recovery period, as shown by the lower RMS and MFCV with respect to the healthy controls following 10 min from the fatiguing contraction.

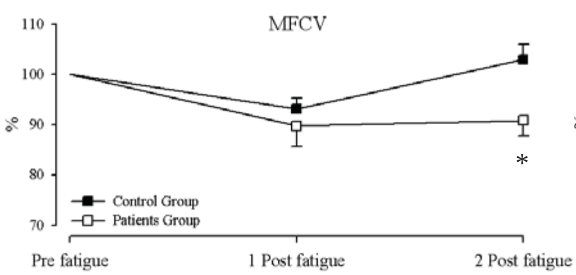

Figure 1: Percentage decline of MFCV (mean±S.E) in the 3 conditions for the 2 groups.
* *significantly different from healthy controls*

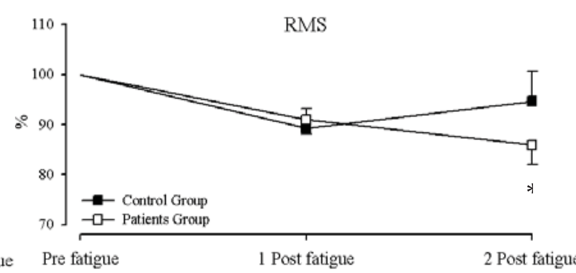

Figure 2: Percentage decline of RMS (mean±S.E) in 3 conditions for the 2 groups.
* *significant interaction between group and condition*

MUSCLE SYNERGIES DURING ON-LINE CORRECTIONS TO REACHING MOVEMENTS

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AIM: Hand trajectories for fast reaching movements toward targets whose location is fixed are straight, stereotyped, and mainly under open-loop control. In contrast, if the target location changes after the movement instruction signal, trajectories are curved, much more variable, and visual feedback must be used for on-line corrections. We have recently shown that the muscle patterns underlying reaching to fixed targets are well described by the combination of a few time-varying muscle synergies, coordinated recruitment of groups of muscles with specific activation waveforms, appropriately scaled in amplitude and shifted in time, supporting the notion of a modular architecture for arm control. Here we investigated whether the muscle patterns for on-line corrections to reaching movements are also generated by the combination of the same set of time-varying muscle synergies used for point-to-point movements.
METHODS: We recorded the position of the wrist and the surface EMG activity from up to 16 shoulder and elbow muscles of five human subjects during reaching from a central location to 8 peripheral targets in the frontal plane (positioned on a circle of 30 cm of radius, radial movements), from each peripheral target to one of the two adjacent targets (tangential movements), and from the central location initially to one peripheral target and, after a delay of 50/150/250 ms from the go signal, to one of the two adjacent targets (target change movements). Subjects were instructed to stop at the final target in less than 550 ms plus the target change delay. Movement direction and type were randomized within each block of trials. Kinematics and EMGs were aligned to movement onset and averaged, for radial and tangential movements, within each movement start and target combination and, for target change movements, within two groups for each target sequence according to the reaction time of the corrective response. Time-varying muscle synergies were extracted from the averaged phasic EMGs of radial and tangential movements and fitted to the patterns of target change movements using an iterative optimization algorithm.
RESULTS: In all subjects, three time-varying muscle synergies explained a large fraction of the data variation (R^2: mean 79 %, range 75 – 84 %) in radial and tangential movements. The same three synergies reconstructed the muscle patterns for target change movements, by allowing the muscle activity to be captured by multiple recruitments of each synergy (R^2: mean 73 %, range 67 – 80 %), better than the superposition of the patterns for the radial movement to the first target location and for the tangential movement from the first to the second location, appropriately aligned (R^2: mean 57 %, range 45 – 66 %).
CONCLUSION: While at the kinematic level the corrective trajectory for reaching during a change in target location can be obtained by the delayed superposition of the trajectory from to original to the shifted target, the underlying phasic muscle patterns are captured by the amplitude modulation and time sequencing of the same time-varying muscle synergies recruited for uncorrected movements. These results suggest that a common modular architecture is used for the open-loop control of arm movement and their visually guided on-line corrections.

ADAPTATION OF LOCOMOTION WHEN WALKING AT HEIGHT: IS VISUAL EXPOSURE OR KNOWLEDGE OF HEIGHT THE PRIMARY STIMULUS?

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AIM: It is known that postural threat induced by height can cause gait adaptations: an increase in double support phase and stride time, a decrease in velocity and stride length have all been reported. However, it remains unknown why these changes occur. Visual information is very important for maintaining balance during posture and locomotion, thus altered visual information is a possible explanation for the more cautious pattern of locomotion. For instance, the loss of familiar ground reference information, and the reduced sway related angular deviation of objects in the visual field when looking down to the ground, provide visual sensations which could be destabilizing to the visual-vestibular balance mechanisms. Furthermore, several studies on postural control have reported a diminished effect when eyes were closed at height. Our aim is to establish if gait changes due to introduced height are primarily associated with what people see or with what they know. If removing the visual exposure of the drop, while retaining knowledge of the drop, eliminates the gait changes made at height then visual information is the primary stimulus. If the cautious gait is unaltered, then cognition is the strongest stimulus.
METHODS: Twelve healthy participants walked along a 22 cm wide 4.8 m long walkway in three different tasks: (i) ground level, (ii) 3.5 m above ground with knowledge an vision of the drop, and (iii) elevated with only knowledge of the drop. Vision of the drop was shielded by horizontal sheets at the same level as and around the walkway. It was demonstrated that the sheets offered no security. Spatial and temporal gait measures were calculated and galvanic skin conductance (GSC) was collected as a measure of physiological arousal.
RESULTS: Walking at height with both knowledge and vision of the drop led to significant changes in all measures: reduction in velocity and stride length, increase in stride time, double support phase (DSP) and GSC. The biggest change was found in time spent in double support, the percentage of time within the gait cycle almost doubled on the walkway at height compared to ground level. Removing visual information of the drop significantly decreased GSC compared to walking at height with visual exposure. However, no significant changes for the spatial and temporal gait measures could be observed.
CONCLUSION: Although GSC did decrease when removing vision of the drop, the gait measures showed no significant changes compared to walking at height. Surprisingly, this indicates that impoverished visual information supplied to the visual-vestibular balance mechanisms is not responsible for the cautious gait observed when walking at height. The primary stimulus is knowledge of the drop. It is therefore the response to that knowledge, and the resulting motor set that leads to the cautious gait. The mechanism through which motor set alters gait requires further investigation.

MOTOR VARIABILITY IN STATIC AND DYNAMIC TASKS BY THE WRIST

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AIM: This study examined the variability of wrist movements in static and dynamic conditions, i.e. a static contraction vs. a tracking task. It was hypothesized that the tracking task would exhibit larger motor variability compared to the static contractions due to the more complex contraction pattern. For this purpose, linear and nonlinear measures were extracted from the surface EMG and kinetic signals to assess motor variability.
METHODS: 12 subjects participated in the study. Force exerted and surface EMG was recorded during wrist movements. Each subject performed a 30 s static contraction and a 30 s tracking task. Contraction levels were set to 20 % maximum voluntary contraction in wrist flexion and extension, as well as ulnar and radial deviation of the wrist. Surface EMG was recorded from extensor carpi ulnaris (ECU), extensor carpi radialis longus (ECR), flexor carpi ulnaris (FCU) and flexor digitorum superficialis (Fdig) muscles. Root mean square, standard deviation and sample entropy measures were extracted from the force and surface EMG signals. Linear measures (standard deviation) were used to assess size of the variability whereas nonlinear measures (sample entropy) reflected the structure of variability. $P < 0.05$ was considered as significant.
RESULTS: When comparing the static and the tracking task, linear parameters like standard deviation of the force signal and root mean square of EMG showed higher values for the tracking contraction ($P < 0.05$) while the opposite occurred for sample entropy of force and surface EMG ($P < 0.05$). In the analysis of different directions of wrist movement, sample entropy did not differ between any of the directions in force output, while muscle activity was different in wrist movements for the flexor muscles (FCU and Fdig), with root mean square values being higher for flexion compared to the other directions and vice versa for sample entropy of surface EMG signals ($P < 0.05$).
CONCLUSION: The findings of this study revealed an increased variability in the task performance for the tracking task compared to a comparable sustained static contraction. This was also underlined by the changes in sample entropy values reflecting complexity. The size and structure of variability of the wrist movements may lead to the design of rehabilitation programs.

EFFECT OF A SHORT-TIME ECCENTRIC AND CONCENTRIC TRAINING IN THE PEAK TORQUE AND EMG ACTIVITY OF THE QUADRICEPS

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AIM: Isokinetic dynamometers assess joint and muscle function under constant velocity conditions and allow for maximal of the muscle in either concentric (CON), isometric (ISO) or eccentric (ECC) mode, throughout the whole range of motion. The isokinetic dynamometers can also be an excellent equipment for training. To identify the effect of concentric and eccentric (ECC) strength training on muscle strength and muscle activation in 2 groups of 9 younger male sport students (CON, n=9, age 21.1±1.1 yrs; ECC, n=9, age 21.2±1.4 yrs).
METHODS: Maximum muscle strength (isometric, isokinetic eccentric and concentric at 60º/sec) was assessed for the dominant leg and synchronized with surface EMG for the Vastus Lateralis (VL), Rectus Femoris (RF) and Vastus Medialis (VM) muscles.
All subjects participated in a 4-week-preparation phase after a 4 week preparation phase consisting of concentric-only training for the dominant leg (3x10 repetitions 60º/seg), subjects were divided into 2 groups, concentric-only (CONG) and eccentric-only (ECCG) training groups. CONG and ECCG performed 3x10 repetitions concentric- and eccentric-only respectively for the dominant leg (3 times/week for 4 weeks).
RESULTS:
Table 1: Mean, Standard Deviation of PT (Nm) and avgEMG (mV) in VL, RF and VM muscles, before and after 4 weeks of strength training, in CONG and in ECCG group training.

			CONCENTRIC GROUP (CONG)			ECCENTRIC GROUP (ECCG)		
			Pre-test	Pos-test	Diff.	Pre-test	Pos-test	Diff.
MUSCLE STRENGHT ASSESSEMENT	CONCENTRIC	VL	.777 ± .298	.935 ± .506	20%	.701 ± .291	1.020 ±.305	41%
		RF	.622 ± .237	.701 ± .236	13%	.691 ± .284	.818 ± .487	25%
		VM	.703 ± .306	.909 ± .276	29%	1.031 ± .725	1.094 ± .376	14%
		PT	221.86 ± 35.76	225.9 ± 24.42	2%	236.38 ± 17.74	221.25 ± 26.59	-6%
	ISOMETRIC	VL	.542 ± .215	.845 ± .529	56%	.401 ± .193	.725 ± .393	64%
		RF	.448 ± .097	.495 ± .195	10%	.519 ± .253	.680 ± .307	26%
		VM	.544 ± .294	.689 ± .215	27%	.501 ± .199	.808 ± .366	56%
		PT	255.45 ± 56.58	263.68 ± 45.18	3%	261.62 ± 29.96	258.19 ± 43.16	-1%
	ECCENTRIC	VL	.663 ± .339	1.017 ± .777	53%	.610 ± .460	.751 ± .331	27%
		RF	.490 ± .217	.609 ± .325	24%	.458 ± .167	.651 ± .380	40%
		VM	.666 ± .372	.707 ± .291	6%	.699 ± .294	.872 ± .372	26%
		PT	286.00 ± 73.40	310.14 ± 90.89	8%	301.25 ± 36.17	330.25 ± 57.90	10%*

* pre to post within-group significant differences, p<0,05

CONCLUSION: This study showed that concentric training improve peak torque (PT) and electrical activation in all kind of contractions (concentric, isometric and eccentric). The eccentric training also improve the electrical activation in all muscles and contractions, but regarding to peak torque just improve in eccentric contractions.

EFFECTS OF A TRAIL RUNNING COMPETITION ON MUSCULAR PERFORMANCE AND EFFICIENCY IN WELL-TRAINED YOUNG AND MASTER ATHLETES

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AIM: Through the growing popularity of trail competitions in the older population, a need to quantify the acute physiological effects of this type of physical activity has arisen. While trail runs are often grouped together with other ultra long endurance disciplines, the large eccentric workload of the knee extensors, procured through the extensive downhill sections of the courses, gives trail races a very specific profile. A 55km, 6000D (6000m vertical displacement) trail running competition was monitored for two age groups (10 young (30.5±7 yrs) and 13 master (45.9±5.9yrs) subjects) in order to describe the effect of the eccentric component and to uncover the differences in post-race response between age groups.
METHODS: 23 subjects completed the above-mentioned event. The study was conceived as an intervention study compromising a familiarization session, pre, post 1h, 24h 48h and 72h measurements. The post measurement consisted of an MVC contraction only, while all other measurements consisted of blood tests, MVC contractions and ergometer cycling at a predefined, constant power output. Parameters monitored included force and EMG [RMS] of an MVC (knee extensors and vastus lateralis), Twitch- and M-wave properties, locomotion efficiency and muscle damage markers in the blood (CK, LDH).
RESULTS: Results indicate age-dependent pre-to-post decreases in MVC values (-32% young vs. -40% master), MVC EMG (-40.2 ± 19% young vs. -42 ± 19.2% master) and in peak to peak duration (+16% young, +21% master). This was accompanied by pre-to-post24 increases in CK and LDH (+988% young vs. +1030% master and +130% young vs. +148% master respectively), increases in twitch contraction time (+9% young vs. +16% master) and concomitant decreases in peak twitch values (-20% young vs. -33% master) and a decrease in locomotion efficiency (-4.7% young vs. -6.3% master).
CONCLUSION: Overall, masters showed greater values in most fatigue and muscle damage markers than young, while achieving similar race times (6:42h young vs. 6:51h master). This indicates an age-dependency of intervention-ensuing fatigue. The gleaned results suggest that trail runs are more detrimental to muscle function than level runs (as compared to literature values), and gives indication that training may not halt muscle deterioration through aging, but can help maintain performance level.

ELECTROMYOGRAPHIC ACTIVITY OF THE MASTICATORY MUSCLES IN INDIVIDUALS WITH TEMPOROMANDIBULAR DYSFUNCTION ASSOCIATED TO GENERALIZED JOINT HYPERMOBILITY

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AIM: to evaluate the presence of generalized joint hypermobility (GJH) and electrical activity of the masseter and anterior temporal muscles in individuals with temporomandibular dysfunction and asymptomatic individuals, comparing them.
METHODS: 61 female volunteers were evaluated, with ages from 18 to 35 years: 34 individuals diagnosed with TMD through the Research Diagnosis Criteria for Temporomandibular Disorder (RDC/TMD) and 27 asymptomatic individuals. These groups were classified in regard to the presence of generalized joint hypermobility according to the Beighton Score. The electromyographic exam (EMG) of the masseter and anterior temporal muscles was carried out bilaterally, in mandibular rest, maximum intercuspal and chewing. The Mann-Whitney test was used to compare the electromyographic activity of the masticatory muscles among the study and control groups and referred subgroups (with GJH and with normal mobility).
RESULTS: The presence of GJH was verified in 64.71% of individuals with TMD and 40.74% of the asymptomatic group. In the electromyographic evaluation, when comparing TMD group and control group at rest, only the temporal left presented higher significant level of electrical activity in individuals with TMD (p=0.0352). There was no difference between groups during chewing and maximal intercuspal position. The volunteers with TMD and GJH presented higher RMS values of the masticatory muscles in relation to individuals with TMD and normal joint mobility, with statistical significance for right (p=0.0232) and left (p=0.0129) masseter muscles. The individuals with TMD and GJH showed higher levels of RMS than the individuals of the control group with normal mobility at rest. In the comparison between individuals with TMD with normal mobility and the control group with GJH, the left masseter muscle presented statistically higher activity in the last one (p=0.0116). In chewing, higher EMG activity was recorded in the control group, with significant difference for the right temporal muscle (p=0.0286).
CONCLUSION: Electrical activity seems to have been influenced by GJH. The higher resting electrical activity and lower during chewing observed in the subjects with GJH suggest that, due to joint instability, these individuals present difficulties in the modulation of the muscular contraction during the maintenance of the mandibular resting position.

RELATIONSHIPS BETWEEN POSTURAL ORIENTATION, SELF REPORTED FUNCTION, HOP PERFORMANCE AND MUSCLE POWER IN PATIENTS WITH ANTERIOR CRUCIATE LIGAMENT INJURY

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AIM: Neuromuscular control, defined as the ability to produce well controlled movements through coordinated muscle activity, is often impaired after injury to the anterior cruciate ligament (ACL). This impairment can for instance be manifested as alterations in the ability to stabilize body segments in relation to each other and to the environment; an altered postural orientation. Despite this, tests to evaluate neuromuscular control after ACL injury are not designed to assess postural orientation. Therefore, we recently started the development of an observational test-battery measuring postural orientation manifested as observable “substitution patterns”, named Test for Substitution Patterns (TSP). In a first study of the TSP, the patients displayed “substitution patterns” more frequently and/or more clearly on their injured, but also on their uninjured side than did controls. Inter- and intrarater reliability was good at a group level. The main aim of the present study was to characterize relationships between the novel test-battery, Test for Substitution Patterns, and commonly used tests of knee function. We also compared TSP scores for patients’ injured and uninjured sides and for patients with a mechanically stable knee (treated with surgical reconstruction) vs. patients with a mechanically unstable knee (treated non-surgically).
METHODS: In a blinded setup, 53 patents, aged 18 – 35 with ACL injury, were assessed on the Test for Substitution Patterns, the Knee Injury and Osteoarthritis Outcome Score subscale sport/recreation (KOOS sport/rec), a battery of 3 hop tests and a battery of 3 muscle power tests.
RESULTS: Moderate correlations were found between TSP scores and KOOS sport/rec (r_s=-0.43; p=0.001) and between TSP scores and hop test scores (r_s=-0.40–-0.46; p≤0.003), indicating that altered postural orientation was associated with worse self-reported KOOS sport/rec function and worse hop performance. No correlations were found between TSP scores and muscle power scores. Patients had higher TSP scores on their injured side than on their uninjured side (median 4 and 1 points; inter-quartile range 2–6 and 0–1.5, respectively; p<0.0001). No difference was found between patents treated with surgical reconstruction and those treated non-surgically (median score injured side 3.5 and 4.0 points; range 0–17 and 0-18, respectively; p=0.88).
CONCLUSIONS: We conclude that the Test for Substitution Patterns is of patient relevance and measures a unique and important aspect of neuromuscular control not fully captured by tests commonly used in patents with ACL injury. The TSP may be a valuable complement in the assessment of neuromuscular control before, during and after rehabilitation in these patents. Notably, we found no indication that substitution patterns were improved by mechanical stabilization per se.

LOW BACK LOADING IN NURSE TRANSLATING PROFESSIONS

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AIM: Over 60% population of the world has had the most common musculoskeletal disease-low back pain. In Taiwan, the nurse-based studies showed about 78% nursing staff with low back pain problem. But little was known about the real spinal loading when the nurses performed patient-handling tasks. The aim of this study is to investigate and evaluate the low back loading of the nursing care who translates patient on bed, and suggest the proper procedures to decrease the risks of low back injuries for nursing cares.
METHODS:10 subjects (clinic nurses) with a mean age of 26.8 yrs (SD=1.3yrs) were divided into two groups. Group A, included six nurses who translating patients horizontally by three steps; i.e., head-foot-trunk. Four were in group B, who translated the patients on bed by pulling patient's clothes directly (one step). During translating tasks, the 3-dimensional motion system, force plate, and EMG were used to capture the experimental data synchronously. Base on the principle of inversed dynamics and EMG assisted optimization technique, the forces of trunk muscle, including Rectus Abdominus (RA), Abdominal Obliques Externus (EO), Erector Spinae (ES), Abdominal Obliques Internus (IO) and external loading on L5/S1 joint, can be evaluated.
RESULTS: The results showed the averaged maximal value of the external moment that acted on the joint was 147.8 ±47.8 N-m, and the internal force acting on the L5/S1 joint of the 10 subjects was 3056.2±743.4 N. Fig. 1 showed the spinal loads of group-A were greater than those of group-B, and the bending moment of group-A was also obvious larger than those of group-B (Fig. 2). The muscle force of the right ES acting on the L5/S1 joint in group A obtained was larger than that of in group B (p=0.049). However, the left RA was lesser in group-A than in group-B (p=0.033). The translating procedure was one of the important factors that caused the significant differences between muscle forces (Fig. 3).
CONCLUSION: Excessive trunk rotation or flexion would increase spinal loading of the L5/S1 joint when nurses perform horizontal repositioning the patients on the bed. Therefore, we suggested that the nurses should perform the translating task in three steps (head-foot-trunk), and in symmetry and erect posture as possible to avoid the excessive spinal loading. In addition, the erect posture would decrease the spinal loading by increasing the co-contraction of the trunk muscle.

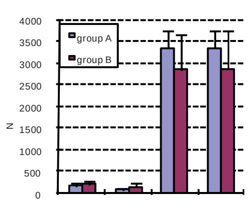

Figure1: Comparison of spinal loads

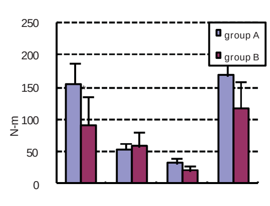

Figure 2: Comparison of spinal moment

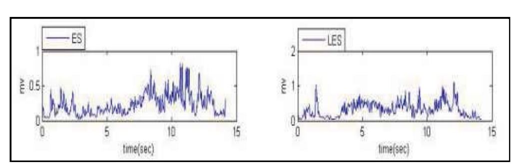

Figure 3: EMG response in erector spinae and left erector spinae muscles

THE CHARACTERISTICS OF BALANCE STRATEGY OF THE TAI-CHI ROUTINE AND PUSH-HANDS PLAYERS

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AIM: Tai-chi had been researched for the benefit in improving balance control. But there have two kind of Tai-chi practicing, Routine and Push-hands style, and most of previous researches were focused on routine players or training. The purpose of this study was to determine the lower limbs muscular activation patterns of Tai-chi Routine and Push-hands players in being pulled without direction notifying, in order to explore the characteristics of balance strategy.

METHODS: There were 6 Tai-chi Push-hands (PG) and Routine players (RG) were drawn from ahead (DA) and backward (DB) six times (per direction was performed three times) in random. Electromyographic activity of 9 muscles of lower limbs included erector spinae (E_spi), rectus femoris (rec), hamstring (ham), tibialis anterior (tib), and gastrocnemius (gas) were recorded with a 2-axis accelerometer on subjects. Raw electromyographic records as 1 s before and after the pulse of accelerometer were rectified, integrated, and normalized.

RESULTS: The main difference between PG and RG was the PG had activation of erector spinae and left hamstring when pull-force came from ahead (Figure 1 (a)). And both PG and RG had the characteristic of the distal muscle (tibialis anterior and gastrocnemius) activated first.

CONCLUSION: When being drawn from ahead, the Push-hands players might use hip joint strategy more than the Routine players. The major balance strategy of both was ankle joints strategy when receiving a balance-breaking force.

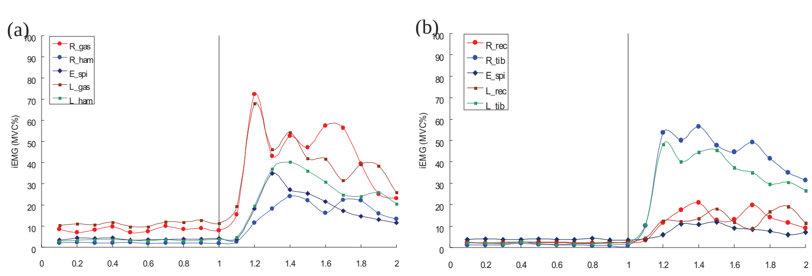

Figure 1: The Push-hands players' muscular activation in being pulled without direction notifying. (a) Drawn from ahead; (b) Drawn from backward.

MUSCLE ACTIVATION PATTERNS OF THE DEEPEST MUSCLES OF DORSAL NECK DURING DIFFERENT TASKS – AN ELECTROMYOGRAPHIC STUDY

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AIM: The aim of this study was to investigate the muscle activation patterns of rectus capitis posterior major (RCPM) and multifidus, during cervical extension tasks.
METHODS: Participants were healthy adults aged between 23 and 40 (4 males and 2 females). Subjects performed two isometric tasks, craniocervical (upper) extension and neck extension with craniocervical joints maintained in a mid position (lower), in a prone position. Neck extension forces were measured by two load-cell systems. Fine-wire electrodes were inserted under the guidance of ultrasound midway between occiput and C2 and lateral to the midline for RCPM, and in the middle of the belly of cervical multifidus at C5. The amplitude of EMG (% MVC) for RCPM and cervical multifidus were plotting against increments of force in 5% increments from 5 to 70% during the tasks. The mean EMG amplitude from the six subjects at different force levels was fitted by the quadrate equation (Fig. 1). A three-way repeated measured ANOVA was used to compare the differences in EMG amplitude among muscles, 4 force increments (5%, 25%, 50%, 70%), and tasks.
RESULTS: The equation of the best fitted curve for the EMG amplitude and force plot differed between muscles and tasks. The RCPM and multifidus EMG amplitude increased with each increment in force (main effect: $p<0.0001$, post hoc all: $p<0.05$) (Fig. 1). The interaction between muscle and task was significant ($p=0.016$). The EMG amplitude of multifidus was greater than that of RCPM in lower cervical extension ($p=0.004$, Fig.1), but the muscles did not differ between tasks.
CONCLUSION: These results show that different neck extension tasks are associated with different patterns of recruitment of neck extensor muscles.

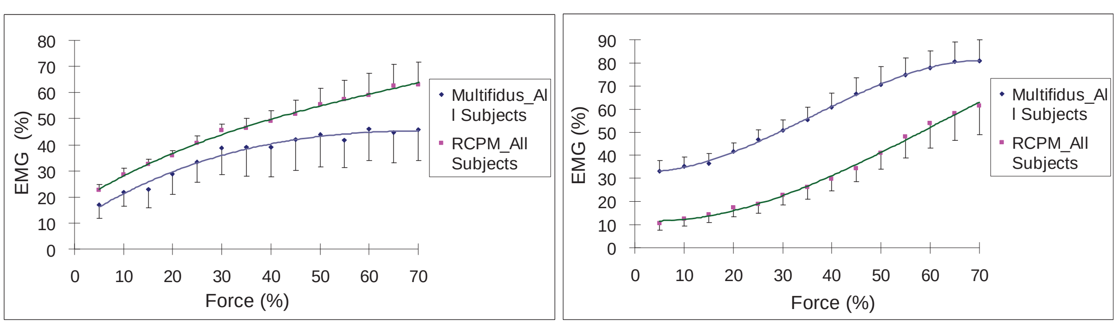

Figure 1: EMG pattern of RCPM and multifidus during isometric craniocervical (upper) extension (left) and during isometric neck extension while maintaining the craniocervical joints in a mid position (lower) (right). (Error bar indicated standard error.)

EMG ANALYSIS AFTER LASER ACUPUNCTURE IN PATIENTS WITH TEMPOROMANDIBULAR DYSFUNCTION (TMD). IMPLICATIONS FOR PRACTICE

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AIM: The aim of this study was to evaluate the immediate effectiveness of low level laser therapy in acupuncture points by assessing the electromyographic activities of masseter and anterior temporal muscles and the range of mandibular movements of patients with articular pain.
METHODS: A total of 10 patients, 1 male and 9 females, mean age of 35.3 years (15 to 67 years-old) were selected for this study by clinical evaluation and anamnestic data showing the presence of temporomandibular pain. A gallium-aluminum-arsenide (GaAlAs) diode laser was used on specific acupuncture points. These were irradiated, bilaterally, for 20seconds (energy density 35 J/cm2), once a week for ten sessions. The points for exposure to laser radiation were selected by reference to authoritative sources on acupuncture (Ig4, C3, E6, E7). Electromyographical analysis of masseter muscle and temporalis muscle was used to assess subjects activities during habitual occlusion and rest position and to compare the results before and after treatment with acupuncture point laser treatment. The electromyographical analysis was also compared to a control group of similar age and gender. Data analysis was performed using a MyoSystem-Br1 (São Paulo, Brazil) electromyographer with differential active electrodes (silver bars 10 mm apart, 10 mm long, 2 mm wide, 20• gain, input impedance 10 GX and 130 dB at 60 Hz common mode rejection ratio). Surface differential active electrodes were placed on skin previously cleaned with alcohol, bilaterally on both masseter muscles and on the anterior portion of the temporalis. A ground electrode was also used and fixed on the skin over the sternum region. The electromyographical signals were analogically amplified with a gain of 1000•, filtered by a pass-band of 0.01–1.5 kHz and sampled by a 12-bit A/D converter with a 2 kHz sampling rate. The signals were digitally filtered by a pass-band filter of 10–500 Hz for data processing. The data collected were normalized by maximum voluntary contraction (MVC), and the results were statistically analyzed using the ANOVA test (SPSS- 17.0- Chicago) during the comparison between groups.
RESULTS: Statistical test analysis showed statistically significant improvements ($p<0.01$) in painful symptoms and electromyographic activities of masseter muscles in habitual occlusion after laser applications but no significant improvements ($p=0.05$) in measurements of mandibular movements.
CONCLUSIONS: The data allow us to conclude that the our results suggest that laser acupuncture may be an effective and stress free initial treatment for the relief of painful symptoms associated with temporomandibular dysfunction.
ACKNOWLEDGEMENTS: Financial support from FAPESP.

INTERVENTIONS WITH BIOFEEDBACK FOR PREVENTION AND TREATMENT OF WORK-RELATED MUSCULOSKELETAL NECK SHOULDER DISORDERS

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AIM: Neck shoulder pain constitutes a major problem in the western society, depending on the case definition the prevalence range from 12 to 70% in the general population. Very few neck pain patients experience a complete resolution of symptoms; among those experiencing neck pain 50 to 85% will report pain again within the next 1 to 5 years. A widely held belief among physiotherapists is that shoulder neck pain primarily is due to lack of stabilization of the scapula and that shoulder neck pain patients have difficulties controlling the scapula. This could either be due to low muscular strength because of activation deficits, or impaired control of muscles stabilizing the scapula.
METHODS and RESULTS: Biofeedback has been known for decades as an efficient way to gain control and activate specific muscles in rehabilitation. Recently, biofeedback of muscle activity (electromyography, EMG) has in laboratory studies proved effective for reducing hyperactivity and also at work places reducing pain in workers with trapezius myalgia (1;2). In a recent RCT study, we have shown that a few learning-sessions with biofeedback lowered the activity and improved the rest of the trapezius during subsequently normal office work without feedback (3). Moreover, we have shown that just 1 hour of biofeedback of subdivisions of trapezius or serratus anterior enabled subjects to selectively activate the lower subdivisions without activating the upper part (4, 5). Therefore, biofeedback on muscle activity is a promising clinical approach for teaching patients a functional healthy muscle activity pattern. Results from an ongoing study, will be presented at this conference showing the use of biofeedback among impingement and myalgic patients to examine the ability of selective activation and enhanced activation of the lower trapezius and serratus anterior in functional test.
CONCLUSION: Based on these results biofeedback will be discussed as a method to change activation pattern in the scapular muscles thereby improving stability and potentially prevent muscular disorders.

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EFFECT OF PROSTHESIS ON MASTICATORY MUSCLES ELECTROMYOGRAPHY ACTIVITY

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AIM: This study evaluated the effects of fixed prosthesis on implants associated with upper complete denture on electromyography of masseter and temporal muscles.
METHODS: Fifty four volunteers divided into two groups: I) 27 Wearers of upper complete denture and fixed prosthesis on implants (Inferior Bränemark Protocol); II) 27 Dentate individuals (Control). Electromyography was carried out in clinical conditions of rest, protrusion, right and left laterality, maximum voluntary contraction and habitual mastication. Surface electromyography was performed using five channels of the Myosystem-Br1 apparatus (DataHominis Ltd.), with simultaneous acquisition and common grounding to all channels. sEMG data were collected using surface differential electrodes (two Ag–AgCl bars, 10 × 2 × 1 mm, with 10 mm interelectrode distance, gain of 20, input impedance of 10 GΩ and common mode rejection ratio of 130 dB – Myosystem, São Paulo, Brazil). EMG signals were sampled by a 12-bit A/D converter board with a frequency of 2 kHz, and band-pass filtered at 0.01–1.5 kHz. Raw sEMG data were digitally filtered at frequency bandwidth of 10–500 Hz and root mean squares (RMS) were calculated. Three maximal voluntary isometric dental contractions (MVCs) were performed for each muscle to normalize the sEMG data (4s).
RESULTS: Rest - A statistically higher electromyographic activity was observed in right masseter and left temporal muscles of individuals from Group I. In dentates, equilibrium in the activities of masseter and temporal muscles was observed. Slight hyperactivity of temporal muscles during rest in comparison with masseter muscles of Protocol wearers was observed. Protrusion - A higher electromyographic activity in Group I was observed. Masseter muscles presented a higher activity than temporal muscles both in Bränemark protocol wearers and dentates. Right laterality - A lower electromyographic activity in individuals from Group I was observed. Left laterality - A higher electromyographic activity in individuals from Group I was observed. Habitual mastication - dentates presented a higher electromyographic activity in all the four muscles analyzed. In both groups, there was a higher activation of masseter muscles.
CONCLUSION: Bränemark protocol generated equilibrium in the electromyography of the tested muscles during the maintenance of postural positions, and allowed patterns similar to those developed by dentate individuals during mastication.

TRAINING EXPLOSIVE MUSCLE PERFORMANCE AFFECTS AGONIST ACTIVATION AND THE MECHANICAL PROPERTIES OF THE MUSCLE-TENDON UNIT

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AIM: The current study investigated changes in the rate of force development (RFD), and neural and mechanical adaptations, following short-term unilateral explosive isometric strength training.
METHODS: Ten males completed 4 sets of 10 explosive isometric knee extensions (1-s contractions completed 'fast and hard'), 4 times a week for 4 weeks. Pre and post training measurement trials consisted of recording force and EMG of the three superficial quadriceps throughout a series of voluntary and involuntary contractions of the knee extensors. Participants completed 10 explosive voluntary contractions to determine force at 50 (F_{50}) and 100 ms (F_{100}) after force onset. To determine agonist activation during 0-50 and 50-100 ms time windows of the explosive contractions root mean square EMG of each muscle was normalised to an evoked maximal M-wave, and averaged across the quadriceps. Participants also completed 3, 3-s maximal voluntary contractions (MVCs) to establish maximal voluntary force (MVF). Supramaximal octet contractions (8 pulses at 300 Hz) were evoked to determine the contractile properties of the muscle. Ultrasonic images of the vastus lateralis were recorded during ramped MVCs to measure muscle-tendon stiffness (slope of the force-aponeurosis displacement curve between 50-90% MVF).
RESULTS: In the trained leg there was an increase in voluntary F_{50} and F_{100}; MVF; octet F_{50} and F_{100}; and muscle-tendon stiffness (Table 1). When normalised to MVF, explosive voluntary F_{50} was greater following training (+53-55%; P<0.05), but explosive voluntary F_{100}, octet F_{50}, and octet F_{100} remained in proportion to MVF after training. Agonist activation of the trained leg only increased in the 0-50 ms time window (Table 1). The only observed effect in the untrained leg was an increase in MVF (Table 1).
CONCLUSION: Enhanced agonist activation during the early phase of the contraction contributed to the substantial increase in explosive voluntary F_{50} following training. The surprising increase in octet RFD demonstrated an improved capacity of the muscle-tendon unit for explosive performance, which may have resulted from increased muscle-tendon stiffness, and likely also influenced voluntary performance.

Table 1: Mechanical and neural variables recorded during maximal voluntary and involuntary isometric knee extensions, pre and post unilateral explosive strength training in the trained and untrained leg. Data are means ± SD. Pre vs. post training differences are denoted with *(P<0.05), **(P<0.01), or ***(P<0.001).

Mechanical or neural variable	Trained leg		Untrained leg	
	Pre	Post	Pre	Post
Explosive voluntary force at 50 ms (N)	90 ± 33	139 ± 47**	91 ± 41	110 ± 46
Explosive voluntary force at 100 ms (N)	288 ± 37	332 ± 47**	287 ± 44	297 ± 51
Agonist activation 0-50 ms (% M_{max})	5.0 ± 2.0	7.1 ± 2.0*	5.3 ± 2.4	6.3 ± 1.9
Agonist activation 50-100 ms (% M_{max})	11.1 ± 2.4	12.8 ± 3.0	11.0 ± 2.1	12.4 ± 2.9
Maximal voluntary force (N)	482 ± 58	535 ± 61***	489 ± 58	508 ± 62*
Evoked octet force at 50 ms (N)	193 ± 11	207 ± 13*	199 ± 30	205 ± 21
Evoked octet force at 100 ms (N)	301 ± 31	330 ± 19*	303 ± 50	320 ± 37
Muscle-tendon stiffness ($N.mm^{-1}$)	468 ± 77	627 ± 92**	532 ± 118	556 ± 167

ERGONOMIC CONDITIONS AND MUSCULAR ACTIVITY AT OFFICE WORK

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AIM: The rapid increase of computer application in occupational work in the last decades has initiated a long-lasting debate whether computer use is a potential cause for the development of pain in the upper body of office workers. Possible reasons for the development of complaints are the long-term activation of muscles in the neck-shoulder-arm region needed for posture stabilization and repetitive movements of high accuracy applied to operate the computer. The study was aimed to investigate working conditions, spatial arrangement of the computer equipment as well as muscular activities and complaints during real office work.
METHODS: In a first part of the study, 69 employees of a tax office participated in a survey regarding their occupational activity, the working tools and the spatial arrangement of the monitor, keyboard and mouse as well as potential musculoskeletal symptoms. In the second part, from a subgroup of 13 employees 4 surface electromyograms (EMG) were recorded in the right neck-shoulder-arm region during total working shifts. Simultaneously the actual activity was documented using an encoding procedure. At four points in time during the day the subjects indicated actual musculoskeletal complaints.
RESULTS: The survey reveals that computer work represents the most frequent activity of the persons, followed by paper work and communication activities such as phoning, speaking, or participating in meetings. Complaints occurring for at least 8 days during the last 12 months were reported from 50% of the persons for the neck and the lower back, and from about 40% and 30% for the right or the left shoulder, respectively.
Evaluation of the total-shift EMG recordings was performed using the previously developed method for ‘Joint Analysis of the EMG Spectrum and Amplitude (JASA)’. Temporal changes in the EMG amplitude and frequency spectrum over the day were used to identify the cause for the EMG changes, namely ‘fatigue’, ‘recovery’, ‘force increase’ or ‘force decrease’. In the actual study, muscular fatigue was found for the hand extensor muscle during keyboard operation and for the right trapezius muscle during paper work among a few persons. For most of the persons a decrease in force production during the day was found. Comparison of the EMG changes with actual complaints indicates that persons with a steeper decrease in the EMG amplitude of the shoulder muscles mentioned a lower number of shoulder complaints than persons with less EMG change. – A specific analysis initiated by the gap hypothesis mentioned in the literature was performed for the trapezius muscle. For about half of the persons a decrease in the rest time, i.e. periods with very low EMG activity, was observed in the course of the working day. This would, assuming the gap hypothesis, indicate an increasing risk for musculoskeletal complaints with increasing working time.
CONCLUSION: For persons with a low number of complaints a reduction of the muscular activation during the working day was found. Hence, such persons perform a self-adjustment of physical activity aiming for the avoidance of pain. It may be concluded that self-organising work sequence and pace comprising a reduction of muscular activation in the course of the working day represents an effective strategy to prevent muscular complaints.

BIOMECHANICAL AND CLINICAL EFFICACY OF LUMBOSACRAL ORTHOSES IN THE MANAGEMENT OF LOW BACK PAIN

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AIM: Lumbosacral orthoses (LSOs) are used in conservative and postoperative management of low back pain (LBP). Biomechanically, they reduce trunk range of motion and increase trunk stiffness. However, the clinical efficacy of LSOs is debated in literature. We hypothesized that non-extensible LSOs would increase trunk stiffness more and would lead to better clinical outcomes than extensible LSOs. Therefore, the purpose of this study was to compare the efficacy of an extensible (Mueller Adjustable Back Brace) and non-extensible (Aspen QuikDraw Pro) LSO to augment trunk stiffness and to improve physical function in patients with chronic LBP.

METHODS: Trunk stiffness was estimated from trunk displacement data in response to a quick force release in trunk flexion, extension, and lateral bending. Fourteen male and 6 female subjects performed five trials for each experimental condition: (1) No LSO, (2) Mueller LSO, and (3) Aspen LSO. Testing order was randomized and LSOs were cinched to a pressure of 70 mmHg (9.4 kPa) measured between posterior aspect of the iliac crest and the orthosis. An additional 63 subjects were randomized to 3 treatment groups (1) No LSO, (2) Mueller LSO, and (3) Aspen LSO. Subjects in the LSO conditions wore the LSOs daily. The Oswestry Disability Index questionnaire was administered at baseline and at 2 to 3 weeks from starting treatment. All data were compared with ANOVA.

RESULTS: On average, the Aspen LSO increased trunk stiffness by 14% ($P < 0.01$), while the Mueller LSO did not result in any significant change in trunk stiffness (Figure 1). At the same time, patients wearing the Aspen LSO demonstrated a 14% improvement in self-reported disability ($P = 0.01$) (Table 1). Although patients wearing the Mueller LSO improved by 9%, this difference was not statistically significant ($P = 0.18$).

CONCLUSION: These data suggest that a non-extensible LSO (made of polyester and nylon) is more effective in augmenting trunk stiffness when compared with an extensible LSO (made of neoprene and lycra). These biomechanical characteristics appear to correlate with improvements in physical function in patients with chronic LBP.

ACKNOWLEDGEMENT: This study was made possible in part by a grant AR051497 from the NIH and in part by a grant from Aspen Medical Products Inc., Long Beach, CA, USA.

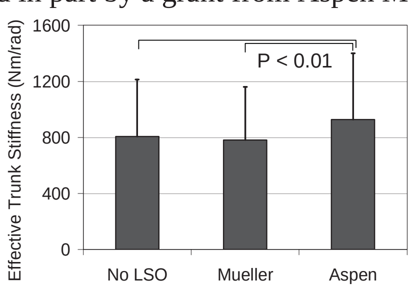

Figure 1: Effective trunk stiffness provided by an extensible (Mueller) and non-extensible (Aspen) LSO. Data were averaged across all quick release directions.

Table 1: The Oswestry Disability Index (ODI) at baseline and after 2 weeks of treatment.

Group	**No LSO**		**Mueller LSO**		**Aspen LSO**	
	Baseline	**2-3 weeks**	**Baseline**	**2-3 weeks**	**Baseline**	**2-3 weeks**
ODI [%]	35 ± 18	35 ± 20	40 ± 12	30 ± 16	39 ± 16	25 ± 18

ASSESSING MUSCLE ACTIVATION PATTERNS IN REALLIFE AND USING THEM AS FEEDBACK TO TREAT CHRONIC PAIN SUBJECTS

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Introduction:
Many models relating chronic pain to physical behavior, predict changes in motor patterns, although with different expressions. Such changes can be observed at different levels:

- At the level of activity of the body expressed as the amount of movements, it was shown recently that patients with low back pain show a changed pattern of activities over the day, with relatively high levels of activity in the morning and low in the evening (van Weering 2008).
- During walking, subjects with back pain tend to show differences in trunk muscle activity, which can be regarded as a “guarding” mechanism (v.d. Hulst 2008).
- Muscle activation patterns may show higher activation levels, less relaxation and more difficulties to relax after activation. With HDEMG it was shown that changes in motor unit properties might occur in chronic neck shoulder pain (Kallenberg 2007).

The many, partially contradicting results from the experimental studies have not resulted yet in one model describing the chronification process of neck/shoulder and low back pain. It however underlines that this process is complicated with many interacting physiological and psychosocial factors. The interactions probably tend to be like a vicious circle, causing changes in the states of motor control, activities and cognitions. With respect to a therapeutic approach, this would imply that this can be done at different levels.

Starting point for a therapeutic approach
Myofeedback has been applied in the seventies with very limited success in trying to restore foot lifting in stroke. A main problem was that the patients could lift the foot in the training set-up in the hospital but were not able to use this ability in real life situations. Requirements for a successful therapeutic approach therefore are that it can be used in daily life situations, not hindering the patient and providing continuous feedback about his performance. The feedback should be personal and direct and enable the subject to respond with a change of his muscle activation pattern. Consequently, this demands the use of unobtrusive stable on-body sensing, ambulant processing and a private feedback.

Results
Garments were developed with dry surface electrodes to enable 24 hours recording of muscle activation patterns for the Trapezius and low back muscles. EMG is processed into a variable expressing relative relaxation time (RRT). Low values result in vibration of the on body system that performs the EMG processing and communication. The system was evaluated in a clinical trial in three European countries (Voerman 2007). During the MYOTEL project (coordinated by Vollenbroek), an ICT platform was added to make central data storage and remote consultation possible. The system was extensively tested during an international trial in four countries in the past years and it was shown that the effects are at least similar to those obtained with more traditional treatment.

EVALUATION OF A NOVEL FUNCTIONAL FATIGUE PROTOCOL

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AIM: Neuromuscular fatigue is believed to be a contributing factor to injury in athletic situations. To examine this idea, it is necessary to establish functional fatigue models that are representative of the type of physical activity that takes place in athletic training and competition. The purpose of this study was to validate a novel functional fatigue protocol (FFP) that reproduces the demands of a sporting situation i.e. accelerating and decelerating the body, changing direction, jumping, landing, and metabolic stress.
METHODS: 8 recreationally active, healthy males were recruited for this study (age: 31.5 +/- 5.0 yrs; height: 181.4 +/- 5.1cms; weight: 75.5 +/- 9.8kgs). Knee extensor isometric peak torque (PT), EMG median spectral frequency of the rectus femoris (EMG MF-RF) and average power in a counter-movement jump (CMJ) were measured prior to and immediately following the FFP, to evaluate its effect on the body. PT was measured on a Biodex dynamometer, CMJs were measured on an AMTI forceplate, and EMG MF-RF was recorded during a sub-maximal (60% MVC) isometric contraction. Blood lactate concentration ($[La^-]b$), heart rate (HR) and rate of perceived exertion (RPE) were also recorded on completion of the FFP, to quantify the intensity of the exercise. A 12m space was marked out in the laboratory. The participant had to run 12m to one line, turn, and run back 12m to the other line. At the end of this shuttle, they then had to quickly perform a vertical jump (VJ) to a target set at 80% of their maximum VJ height. In order to normalize the participant's running velocity, they first performed 10 repetitions at maximum effort. An average time was calculated for one repetition, and a beep interval was then set at 125% of this time. The participants ran in time to this beep interval, until they were unable to maintain the tempo. One-tailed dependant t-tests and Cohen's d effect-size calculations were undertaken to analyse the pre and post differences in PT, average power in the CMJ, and the slope of the regression line fitted to a plot of the change in EMG MF-RF over a 60s interval..
RESULTS: Participants reported an average RPE of 17.625 +/- 1.187. Their final HR was 177.6 +/- 8.15 bpm. The mean $[La^-]b$ was 8.1 +/- 3.02mmol/l. The average time taken for the fatigue protocol was 18.77 +/- 9.14 minutes. Table 1 shows the p-values and Cohen's d for the outcome measures.
Table 1: p-values and effect sizes for measures of fatigue. ** statistically significant.

Outcome measures	**Pre** mean (SD)	**Post** mean (SD)	**Difference** mean (SD)	**p- value**	**Cohen's d**
Average power CMJ (W)	680.2 (230.1)	713.7 (275.3)	-33.4 (94.1)	0.161	-0.13
Knee extensors PT (Nm)	297.4 (63.7)	265.1 (54.3)	32.3 (42.9)	0.043**	0.56
Slope EMG MF-RF	-0.32 (0.23)	-0.46 (0.24)	0.14 (0.2)	0.086	-0.55

CONCLUSIONS: We conclude that despite all participants reporting high RPE scores, the chosen outcome measures did not fully reflect this. Only the reduction in PT was found to be statistically significant, although medium effect sizes were observed for the change in both PT and EMG MF-RF, as a result of the FFP. High variability in individual fatigue responses was also noted. These results highlight the complexities associated with the implementation of effective fatigue protocols in kinesiological research.

THE EFFECT OF ANTIDEPRESSIVE AND ANTIPSYCHOTIC DRUGS ON MASTICATORY FUNCTION IN INDIVIDUALS WITH SCHIZOPHRENIA AND AFFECTIVE DISORDERS

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AIM: The masticatory function occurs due to the interrelationship between various organs of the stomatognathic system, proprioception, brain centers and occlusal function. Any change in the occlusion information or masticatory muscles can affect the pattern of their movements and the masticatory efficiency. Drugs used in psychiatric disorders treatment are influent on muscular system as a whole. The use of antidepressant and antipsychotic medications causes chronic and acute motor collateral effects that appear on around 20% treated patients.
METHODS: The aim of this study was to compare the sEMG activity of the masticatory muscles during habitual mastication between 20 individuals with schizophrenia (GI), 20 individuals with affective disorders (GII) and 40 controls (GIII). The sEMG analysis was performed using a EMG MyoSystem-BR1 with differential active electrodes (silver bars 10 mm apart, 10 mm long, 2 mm wide, 20x gain, input impedance 10 GΩ and 130 dB common mode rejection ratio). Surface differential active electrodes were placed on the skin, bilaterally on both masseter and temporal muscles. A ground electrode was also used and fixed on the skin over the sternum region. The sEMG signals were analogically amplified with a gain of 1000x, filtered by a pass-band of 0.01-1.5KHz and sampled by a 12-bit A/D converter with a 2 KHz sampling rate. The habitual chewing was verified through the sEMG signal obtained during chewing of five peanuts and five raisins. The electromyographic signals of all the masticatory cycles were collected in three replicates of ten seconds, intercalated by two minutes of rest and, after this process, it was used the mean value. The masticatory efficiency of cycles between individuals was evaluated by the ensemble average of the electromyographic signal, and this value was obtained in microvolts/second, during the time. The values of ensemble average were normalized by the value of the electromyographic signal of maximum dental clenching, harvested by four seconds. The electromyographic means were tabulated and subjected to statistical analysis using ANOVA (SPSS 17.0).
RESULTS: The psychiatric individuals presented higher EMG activity than control individuals with a statistical significance between groups (Table 1) ($p<0.05$).
CONCLUSIONS: The data allow us to conclude that the mental health medication had a stronger influence on the masticatory muscles activity, causing an exaggerated recruitment of muscle fibers to perform a dynamic activity. The results may provide valuable data to be considered when choosing one of these treatments for psychiatric patients, which will improve their quality of life.
ACKNOWLEDGEMENTS: Financial support from FAPESP

Table 1: Normalized sEMG activity of the masseter and temporalis muscles according the mastication task. All data presented statistical significance between the groups ($p<0.05$).

Group	**Masseter**		**Temporalis**	
	Right	**Left**	**Right**	**Left**
Raisins GI	2.23	2.66	1.78	1.54
Raisins GII	2.14	2.07	2.72	1.71
Raisins GIII	1.41	1.19	1.18	1.32
Peanuts GI	2.94	2.75	2.14	1.78
Peanuts GII	3.37	3.2	2.62	2.2
Peanuts GIII	2.4	2.03	1.72	2.02

THE ALPHA-MOTONEURON POOL AS TRANSMITTER OF RHYTHMICITIES IN CORTICAL MOTOR DRIVE

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AIM: Corticospinal interaction gives support to the conceptual mechanism called communication through coherence, which is the assumption that neuronal groups communicate through coherent oscillatory activity. In this respect it is interesting how centrally evoked oscillatory phenomena are translated into EMG activity. We investigated the transfer properties of central drive transmission via the alpha-motoneuron pool to the muscle.

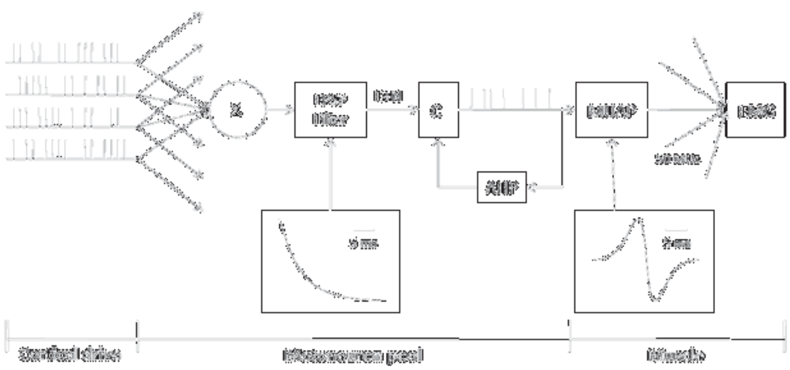

Figure 1: Schematic representation of the model of a motoneuron pool. An exponentially shaped afterhyperpolarization (AHP) is a crucial element in this model.

METHODS: A model based on that of P. Matthews (J Physiol. 1996;492:597-628) was constructed (Figure 1). This model was used for the simulation of alpha-motoneuron firing patterns and the EMG signal as response to central drive input. Short-term synchrony was introduced by assuming a common input to each pair of alpha-motoneurons. The cortical input was modulated to investigate the transfer through the alpha-motoneuron pool in the frequency domain. Coherence between stochastical central input and EMG signal is also evaluated. Furthermore, the effect due to the often-used EMG rectification is investigated.
RESULTS: Modulated cortical input is transferred with only a limited level of non-linearity. The alpha-motoneuron firing frequencies do play a role in the frequency distribution of the amplitude spectrum. However, no preference over proportionality in the region of the firing frequencies was found. Coherence analysis between the summed central input to the alpha-motoneuron pool and the EMG signal is large whereby the coupling strength does not depend on frequency in a range from 1 to 100 Hz. Common central input to pairs of alpha-motoneurons strongly increases the coherence levels as well as the amplitudes in the frequency spectrum. Rectification of the EMG signal introduces a clear frequency dependence. Especially the motoneuron firing frequency range is emphasized.
CONCLUSION: Centrally evoked oscillatory phenomena are strongly transmitted via the alpha-motoneuron pool. The motoneuron firing frequencies do play a role in the transmission gain, but do not influence the coherence levels. Rectification of the EMG signal enhances the transmission gain, but lowers the coherence and introduces a strong frequency dependency. Because of its non-linearity, we think that rectification should better be avoided.

MOTOR UNIT RECRUITMENT STRATEGIES DURING DEEP-TISSUE PAIN

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Movement is changed in pain. Despite intensive investigation, relatively simplistic mechanisms have been proposed to explain the neurophysiological basis for these changes. The widely accepted "pain adaptation" theory argues, very simply, that the nervous system adapts to pain by a uniform reduction in activity of muscles that generate painful force/movement, and a uniform increase in activity of muscles that oppose painful force/movement. Although this is supported by observation of muscle contraction behaviour during some specific movements, our recent data show changes in discharge of motor units (i.e. motoneurone and innervated muscle fibres) during pain that cannot be explained by this theory. Although discharge of some motor units reduce with pain (consistent with pain adaptation theory) other motor units increase discharge (both increase in discharge rate and/or newly recruited units during pain). Thus, excitability of motoneurones in painful muscles is not uniformly decreased. Instead there is a change in motor strategy. This observation questions the interpretation of a large body of research. Our new hypothesis is that rather than uniform inhibition of the motoneurone pool, there is reorganisation of the strategy of motor unit recruitment within muscles to reduce pain and/or protect the painful part. We have tested the robustness of our observation in a range of different muscles, when pain was induced in the test muscle, synergist muscles and non-muscular tissue. Furthermore, the changes in recruitment strategy are also observed when there is threat of pain with no nociceptive stimulation. The changes in motor unit recruitment strategy may be associated with a departure from orderly recruitment of motor units that is expected to occur from smallest to largest, or with a change in the direction of resultant muscle force. Data from our recent work suggest that changes in movement direction, explain the findings, at least in part. We hypothesise that the change in recruitment strategy aim to change the distribution of activity within the muscles to be less provocative of pain. These data have important clinical implications as these changes in coordination may provide a basis for adaptation in loading that could underlie the persistence or recurrence of pain. Taken with other data from behavioural studies we suggest that the motor adaptation to pain: 1. Leads to "protection" from further pain or injury, or threatened pain or injury; 2. Involves redistribution of activity within and between muscles; 3. Changes the mechanical behaviour; 4. Is not explained by simple changes in excitability, but involves changes at multiple levels of the motor system and these changes may be complementary, additive or competitive; 5. Has short-term benefit, but with potential long-term consequences due to factors such as increased load, decreased movement, decreased variability.

ACKNOWLEDGEMENT: This work is supported by the National Health and Medical Research Council of Australia.

MEASURING REAL-TIME EMG AND KINEMATICS IN SURGEONS COMPARING OPEN, LAPAROSCOPIC AND ENDOVASCULAR SURGERY

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AIM: The present study aimed to examine the movements and muscle loading of surgeons during different types of surgical procedures, namely open, laparoscopic and endovascular. These different procedures have been known to require different postures and muscle efforts in the surgeons, who are at risk of developing work-related musculoskeletal disorders.
METHODS: Twenty five surgeons participated in the study (23 males, 2 females). Altogether 47 trials of biomechanical data have been collected over a one-year period. Prior to entering the operating room (OR), surface electromyography (sEMG) electrodes were attached to bilateral cervical erector spinae (CES), upper trapezius(UT) and anterior deltoid (AD) muscles of the surgeon, with standard skin preparation procedures. Biaxial inclinometer was attached to the surgeon's head via a headband and biaxial electrogoniometers were attached over the shoulder joints. These were attached onto the surgeon under the gown in such a way that it would not cause any undue restriction on the surgeons' movements, and the surgeon would scrub up, enter the OR and perform the surgery in their usual manners. The research team monitored the data collection process within the OR on the side. Synchronised kinematics and sEMG were recorded for 30 minutes to over 1 hour, during 3 types of surgical procedures: open, laparoscopic and endovascular. The surgeons were also asked to rate any musculoskeletal symptoms before and after surgery.
RESULTS: The results showed that surgeons maintained significantly greater cervical flexion in open procedures (mean=$27.0^{o}\pm13.6$) compared to laparoscopic (mean=$12.0^{o}\pm7.4$). Mean neck posture (38.9^{o}, p=.001) and mean left shoulder abduction posture (13.2^{o}, p=.001) were significantly different in between these two types of surgery. Median amplitudes in the CES and UT muscles were significantly higher in open surgery compared to endovascular and laparoscopic procedures, whereas muscle activities were fairly similar between endovascular and laparoscopic surgery. The surgeons also reported higher musculoskeletal symptom scores in open compared to the other procedures.
CONCLUSION: This study was one of the first to record real-time movements and muscle activity in the surgeon in such a variety of different surgical procedures and for such long durations. Past studies have only attempted to record EMG and kinematics during simulated surgery or only for short periods (5-10 mins) in the OR. However, the data collection process was developed by overcoming many challenges. The team had to perform the preparatory steps in a very short time as the surgeon's time is very precious. Interference of electrical signals from some surgical equipment was also a problem and noise data had to be removed. We could only attach electrodes to the cervical and shoulder region, and the forearm and hand region could not be examined. The present study has shown that open surgery required greater muscular efforts and involved more flexed posture from the surgeons, and these were associated with greater musculoskeletal symptoms. However past research has suggested that laparoscopic surgery could be more physically demanding due to long durations and static postures. Further research is required to examine various muscle loading and fatigue phenomena in different types of surgery. ACKNOWLEDGEMENT: The authors would like to acknowledge the Bupa Foundation for funding this research project.

REGIONAL DIFFERENCES IN ABDOMINAL MUSCLE ONSET

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AIM: To investigate spatial and temporal differences in location of muscle onset in deep abdominal muscle layers.
METHODS: Twenty-four subjects (age 21 – 60 years) with chronic non-specific low back pain participated in the study. Ultrasound strain rate (US_{SR}), derived from tissue velocity imaging, was used to determine latency time, location, and sequence of muscle onset in abdominal muscles. The subjects performed four rapid arm flexions in response to a light signal while US recordings were made from the abdominal muscles on the contralateral side. The average latency time of the four contractions per subject was used in the analyses. The examined muscles were transversus abdominis (TrA), superficial and deep obliquus internus abdominis (OI_{deep} and OI_{sup}), and obliquus externus abdominis (OE).
RESULTS: First onset was detected more frequently in OI than in TrA (80% vs. 20% of detected onsets; Figure 1a). Moreover, first onset in OI_{deep} occurred on average 53 ms before OI_{sup} (Figure 1b). No single or averaged muscle onset was detected first in OE.
CONCLUSION: This study indicates that the first abdominal muscle onset in response to a postural perturbation occur more frequently in OI than in TrA. Moreover, the OI muscle appears to be divided into a superficial and deep region, where the deep region is activated significantly earlier than the superficial region.

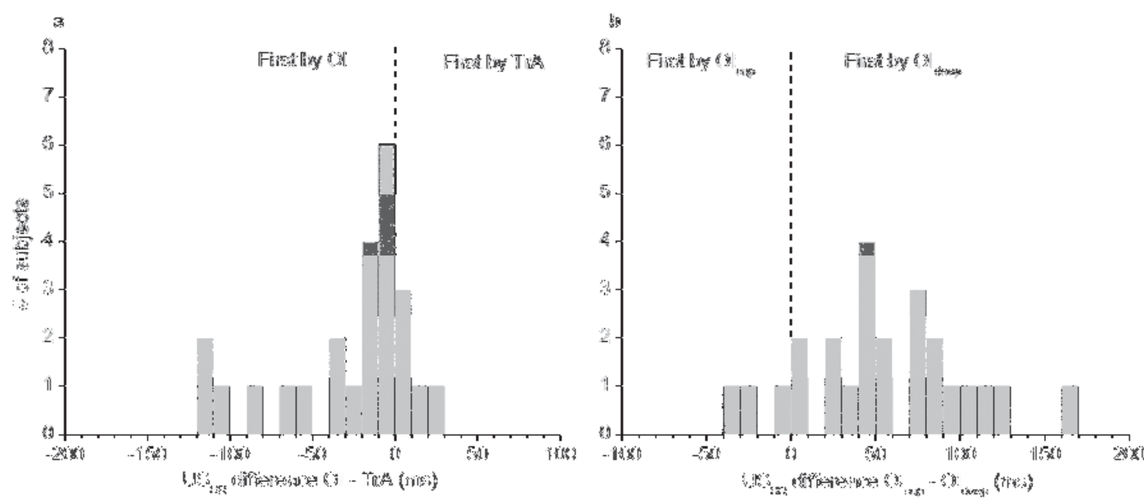

Figure 1: Histograms showing temporal distribution of differences (ms) for onsets in OI minus TrA (a) and OI_{sup} minus OI_{deep} (b). Values are based on the average of 4 contractions per subject (n=24).

MOTOR UNIT SYNCHRONISATION IS ALTERED DURING PAIN

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AIM: Motor unit recruitment strategies are altered during force-matched contractions with pain. These changes include 1) reduced discharge rate and/or cessation of firing of one population of units, 2) increased discharge rate of a small population of units, and 3) the recruitment of new units during pain that were not observed during the pain free contractions1. Additional changes in motor unit recruitment strategies during pain are possible, but have not yet been investigated. Discharge of motoneurone pairs become more synchronised by increased common input under a range of conditions2. The synchronisation of motor units increases twitch force and may be important in the maintenance of force when discharge rate of a population of units is decreased. Synchronisation of motor unit discharge in separate heads of the quadriceps muscle (medial/lateral) is decreased in knee pain3, yet synchronisation of motoneurone discharge within a muscle is increased in delayed onset muscle soreness1 following eccentric exercise. However, in the latter case increased synchronisation precedes pain onset. To determine if motor unit synchronisation is altered within a muscle and between synergist muscles during painful constant-force contractions compared to non-painful contractions.

METHODS: Fine-wire EMG electrodes were inserted into the medial and lateral heads of the quadriceps muscle of 7 subjects. Participants sat comfortably and isometrically contracted their quadriceps with either visual force feedback or auditory feedback of a single motor unit discharge. A transducer attached to the participant's leg just above their ankle and to the chair monitored knee extension force. The contraction strength was equivalent to that required to recruit 3-8 single motor units in any of the fine-wire electrode recordings. Contractions were held for between 30s and 2 minutes, and were repeated until a total of 2-3 minutes of consistent single motor unit firing was observed. Pain (reported intensity ~6/10) was then induced in the patella fat pad by single bolus injection (0.25ml) of hypertonic saline (5%NaCl), and the contractions repeated. Motor unit action potentials were sorted based on morphology. Pairs of single motor units that were present both before and during pain were analysed for synchronisation. Synchronisation strength was calculated using synchronisation index (SI(E)) using standard methods2 as this measure is not affected by discharge rate3.

RESULTS: Within muscle: A total of 39 unit pairs were recorded from within a quadriceps head (19 and pairs from within the lateral and medial heads, respectively). Synchronisation increased significantly with pain from 0.011(0.01) to 0.019(0.01), $P<0.005$. Between synergist muscles: A total of 34 single motor unit pairs were recorded between the quadriceps heads. Synchronisation was not altered in these units with pain (No pain: 0.02(0.02); Pain: 0.02(0.01), $P=0.36$).

CONCLUSION: An increase in within-muscle synchronisation of motor units may help explain maintenance of force when motor unit discharge rate is decreased during pain, and may be a protective strategy used for fast force production during pain.

[1] Tucker et al J Neurophysiol 2009; [2] Dartnall et al J Neurophysiol 2008; [3] Turker & Powers J Physiol 2002

THE EFFECT OF COMBINED MOVEMENT THERAPY FOR PATIENTS WITH SUBACROMIAL IMPINGEMENT AFTER SUBACROMIAL INJECTION

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AIM: Patients with subacromial impingement syndrome (SAIS) have been reported to demonstrate decreased shoulder range of motion (ROM), muscle strength and abnormal scapular control strategies during shoulder movement. Sodium hyaluronate (SH) injection has been widely used for the reduction of pain or inflammation, and several studies have provided evidence to support joint mobilization techniques in reducing clinical symptoms or improving scapular control strategies especially for patients with SAIS. However, no studies have investigated the effects of mobilization with movement (MWM) on clinical symptoms and scapular control strategy for SAIS patients who had SH injection. The study aimed to examine the immediate effect on related symptoms and scapular control strategies for SAIS patients undertaking SH injection and mobilization with movement technique.
METHODS: 10 patients with subacromial impingement syndrome were recruited to take SH injection and mobilization with movement treatments. Pain status, shoulder ROM (flexion, abduction, external and internal rotation), scapular motion (scapular upward rotation, internal rotation and posterior tipping) and scapulohumeral rhythm (SHR) during shoulder scaption were measured before SH injection and one day after injection to examine the immediate effect of subacromial injection. And all the subjects re-evaluate the treatment effect after 1 session of MWM. 3-D scapular kinematics and glenohumeral elevation and lowering were obtained by an electromagnetic motion tracking system (Polhemus Inc.,Colchester,VT,USA). Repeated measures ANOVA and LSD (least significant difference) post hoc test were performed to examine the treatment effect of SH injection or mobilization with movement.
RESULTS: Our study shows significantly improvement in pain status and in shoulder flexion and abduction ROM after SH injection. However, there was significantly decreased scapular upward rotation during elevation, and also a trend of increased scapular internal rotation, decreased posterior tipping was found. In contrast, not only the pain status and shoulder ROM improved after 1 session of MWM, but also improved the scapular control strategies and SHR during scaption.
CONCLUSION: Immediate effect of SH injection was found in pain reduction, improvement of shoulder ROM but not in scapular kinematics. Additional MWM after injection have provide more significantly immediate effect on clinical symptoms(especially in IR and ER ROM) and scapula control strategies. In other hand, Injection of SH is an expensive treatment, and continuous subacromial injection might increase the risk of infection. So MWM treatment was strongly recommended for SAIS patients that just had one shot of SH for better outcome or more lasting effect.

THE APPROXIMATE ENTROPY OF THE ELECTROMYOGRAPHIC SIGNALS OF TREMOR CORRELATES WITH THE OSMOTIC FRAGILITY OF HUMAN ERYTHROCYTES

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AIM: To find if there is some correlation between electromyographic signals of physiological tremor and ageing, using osmotic fragility of human erythrocytes as age marker.
METHODS: The data were collected from 44 healthy volunteers (24-87 years). The osmotic fragility was spectrophotometrically evaluated by the dependence of hemolysis, provided by the absorbance in 540 nm (A_{540}), on the concentration of NaCl. The data were adjusted to curves of sigmoidal regression and characterized by the half transition point (H_{50}), amplitude of lysis transition (dx) and values of A_{540} in the curve regions that characterize the presence of lysed (A_1) and preserved erythrocytes (A_2). The approximate entropy was estimated from EMG signals detected from the extensor carpi ulnaris muscle during the movement of the hand of subjects holding up a laser pen towards an Archimedes spiral, fixed in a whiteboard. The evaluations were carried out with the laser pen at rest, at the center of the spiral, and in movement from the center to the outside and from outside to the center.
RESULTS: The values of A_1 presented a considerably strong and inverse correlation (R^2 = 0.9521) with the volunteers' age. Negative correlations with age were found for dx too (R^2 = 0.8800). With the hand at rest, a positive correlation with H_{50} was found for the approximate entropy (R^2 = 0.9397). Negative correlations with H_{50} were found for the approximate entropy of EMG signals with the hand in movement, as from the center to the outside or from the outside to the center of the spiral (R^2 = 0.9374).
CONCLUSION: (a) The occurrence of a negative linear correlation between the values of A_1 and age of the volunteers should reflect the tendency of older individuals to present lower levels of hemoglobin. (b) The decline in dx with age may represents the behavior of other post-mitotic cells of the body, such as neural and muscle cells. If this hypothesis is correct, there should be some correlation between parameters associated with the stability of red blood cells (A_1, A_2, H_{50} or dx) and approximate entropy of the tremor, since this parameter is the result of neuromuscular interactions. In fact, the values of approximate entropy of hand tremor at rest and in motion showed significant correlations with the values of H_{50}. (c) The entropy of the rest tremor increased with the decrease in the stability of erythrocytes.
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CHANGE OF BRAIN PERFUSION AFTER PERFORMING CYCLING WHEEL CHAIR EXERCISE FOR THE PATIENTS WITH WALKING DISABILITY

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AIM: Cycling wheel chair (C-W/C) is a useful tool to provide a chance of physical exercise for the patients with severe impairment in lower extremities. We developed a new C-W/C with a round shaped steering system. Seki et al reported driving a C-W/C elicited augmentation of paralytic muscle activity in the patients with severe hemiplegia. It was also reported that most of the non-ambulatory elderly could drive a C-W/C and they became psychologically active by realizing self-locomotion. However, long-term effects of driving a C-W/C are unknown especially in the aspects of functional and physiological change. In the present study we made a preliminary investigation to answer this question, namely examined the change of brain perfusion and fitness before and 4weeks after training with C-W/C for the patients with lower extremity impairments.

METHODS: Seven patients with lower extremity paresis in the unilateral side participated in this study. C-W/C is a wheelchair with a pedaling system installed in front of the seat. C-W/C used in this study had a round shaped steering system that is convenient for the patients with upper limb impairment. All of the subjects performed a session of C-W/C training 5days a week adding to standard physical therapy during 4weeks. They drove a C-W/C at their own pace on an indoor course 50meters in circuit during 3minutes continuously. One session of C-W/C training in a day included 5times of continuous driving with 1minute rest between each driving. Total of driving distances in a training session was measured by an odometer installed on a C-W/C. Brain perfusion was examined by measuring time averaged perfusion (TAP) of middle cerebral artery in the healthy side (cm/sec). The probe to measure TAP was attached to the temporal skull of the healthy side. TAP examinations were performed before and 4weeks after start of C-W/C training:

RESULTS: AP could be measured in all of the subjects. The initial value of TAP was almost same as that of normal control. The value of TAP significantly increased in these seven subjects 4weeks after C-W/C training. Total of driving distances in a training session at the end of 4weeks training also increased comparing to the initial level.

CONCLUSION: C-W/C has an advantage to give some pleasure of self-locomotion to the patients with impairment in lower extremities compared to a recumbent type ergometer. Physical load of driving a C-W/C is relatively low but for the patients with poor physical function it may be favorable to improve cardio-respiratory fitness and to provide brain activation. Application of C-W/C training to the patients with various levels of clinical stage is necessary in future.

FATIGABILITY OF THE CERVICAL EXTENSOR MUSCLES WHILE DOING THE NECK EXTENSOR MUSCLE ENDURANCE TEST (NEMET) IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS AND HEALTHY SUBJECTS

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AIM: determine whether patients with myogenous and mixed TMD have greater fatigability of the cervical extensor muscles while performing a neck extensor muscle endurance test (NEMET) when compared to healthy control subjects.
METHODS: 151 subjects participated in this study. 47 subjects were healthy, 57 subjects had myogenous TMD and 47 subjects had mixed TMD. All subjects underwent a clinical examination by a physical therapist to determine inclusion for this study. The electrodes were located over the distal half of the distance between the base of the occiput and the spinous process of the seventh cervical vertebra as described by Falla et al. Each subject was in prone position lying on a plinth with their head and neck initially supported over the end and arms alongside their trunk. A strap was placed across the T2 level in order to counter support the thoracic spine. A Velcro strap was fixed around the skull at the level of the forehead. An extendable tape was attached to the Velcro strap at the point of the subject's eyebrows and hanging at 3 cm from the floor connected with a visual feedback. Thus, this extendable tape indicated when the subject had lost the position. The subjects were instructed to maintain the position as long as possible with the neck unsupported, stopping at signs of fatigue or any discomfort. Data acquisition was sampled at 1024 Hz, amplified to 10000 (kilogain) and filtered 20-450 Hz for the analyzed muscles. To allow comparisons between subjects, the time course of each EMG variable was normalized with respect to the intersection of the regression line in the fatigue plot. Thus, an EMG fatigue index was obtained for every subject and was compared between patients with TMD and control subjects. IGOR Pro5.1 was used to analyze EMG data. The endurance of the neck extensors was also measured recording the time in seconds until the end of the test. A one way ANOVA test was used to evaluate the differences in holding time between patients with TMD and healthy subjects. Paired comparisons were administered to evaluate the differences in holding time between groups. A mixed model analysis (using a natural cubic spline) was used to evaluate the differences in normalized median frequency (EMG fatigue index) at different times for the cervical extensor muscles while performing the NEMET between subjects with TMD and control subjects. SPSS 17.0 and STATA 10 were used to perform the statistical analysis using an $\alpha = 0.05$.
RESULTS: A large variability of the normalized EMG activity across conditions and groups was observed. There were statistical significant differences in slopes of the normalized median frequency between subjects with TMD and healthy subjects at 10, 30, 40, 50, 60, 70, 80, 90, and 100 seconds of the NEMET. Holding time was significantly reduced in both subjects with myogenous TMD and mixed TMD when compared with healthy subjects.
CONCLUSION: These results highlight the fact that alterations of endurance capacity of the extensor cervical muscles could be implicated in the neck-shoulder disturbances presented in patients with TMD.
ACKNOWLEDGEMENT: Susan Armijo-Olivo is supported by the Canadian Institutes of Health Research, Alberta Provincial CIHR Training Program in Bone and Joint Health, and Physiotherapy Foundation of Canada. This Project was funded by the Physiotherapy Foundation of Canada (PFC) through an Alberta Research Award and by the University of Alberta.

sEMG ACTIVITY OF MASTICATORY MUSCLES IN BRAZILIAN WOMEN WITH MAXILLARY AND MANDIBULAR OSTEOPOROSIS

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AIM: Osteoporosis is considered a serious public health issue and one of the most important aging-associated diseases, affecting millions of people in the world. The purpose of this study was to analyze the electromyographic (EMG) activity in Brazilian women diagnosed with osteoporosis in the maxillary and mandibular regions, considering the habits and conditions that lead to development of generalized skeletal bone loss, including on face bones, can disturb the functional harmony of the stomatognathic system.
METHODS: Twenty-seven women with mandibular and maxillary osteoporosis and 27 healthy controls volunteered to participate in the study. Surface differential active electrodes (two 10 mm-long and 2 mm-wide silver-chloride bars, separated by a distance of 10 mm, with input impedance of 10 GW and common-mode rejection ratio of 130 dB at 60 Hz) were used in the study. The skin region where electrodes were placed was cleaned with alcohol and shaved when necessary. The differential active electrodes were positioned in the ventral region of both masseter muscles and in the anterior portion of the left and right temporalis muscles. The position of the electrodes was determined by palpation and they were fixated with adhesive bandage tape, with the longest extension of the bars perpendicular to the direction of the muscle fibers. A stainless still circular electrode (3 cm of diameter) was also used as a reference electrode (ground electrode), fixated on the skin over the frontal bone region. Muscle activity was evaluated by means of EMG recordings of the masticatory musculature (masseter and temporalis muscles, bilaterally) during the following clinical conditions: rest (5 s); right and left lateral excursions (5 s); protrusion (5 s); maximal dental clenching on Parafilm (4 s) and maximal voluntary contraction (4 s). This latter clinical condition was used as the normalization factor of the sample data.
RESULTS: During the clinical mandible posture conditions, like rest, right and left lateral excursions, and protrusion, it was observed that the subjects with osteoporosis showed greater EMG activity for all the analyzed muscles, compared to control subjects, without osteoporosis. For maximal dental clenching, however, control subjects presented greater EMG activity with a tendency for statistical significance at $p<0.05$ (t-test – SPSS).
CONCLUSION: It may be concluded that facial osteoporosis can interfere on the patterns of masticatory muscle activation of the stomatognathic system.
ACKNOWLEDGEMENT: This study was supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo.

ESTIMATION OF FASCICLE COUNT AND DIAMETER IN PIG MEDIAN AND ULNAR PERIPHERAL NERVES

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AIM: The understanding of the morphological, intrinsic mechanical behavior and electrical characteristics of the large human sized peripheral nerve plays an important role in development of new neural interfaces for selective stimulation or recording. Here we aim to gain insight of the morphological structure of the peripheral forelimb nerves in a large nerve animal model.
METHODS: Pig nerves are geometrically and functionally similar with human nerves. A total of 12 specimens from the Median and Ulnar nerve were harvested from both upper limbs of 6 female Landrace-Yorkshire pigs (<50 kg). Nerve samples were taken from 5 different levels of the nerve, i.e. 3 levels just above the elbow joint and 2 levels below it. Approximate nerve circumference at each level was measured by tying a suture around it and then measuring the suture length. A standard Hematoxylin and Eosin stain (H&E) was used for staining to study the morphological structure. Digital pictures were first taken through a microscope of all histological slides. The free software Axio Vision (Axio Vs40 v. 4.6.30, Carl Zeiss Imaging solutions GmbH, Germany) was then used for image analysis. Each picture was loaded into the software. The fascicles were visually identified and counted. Then the fascicle diameters and surface area were measured (Table 1).
RESULTS: The Median nerve contains a higher number of fascicles than the Ulnar nerve at all levels. For both type of nerves the highest number of fascicles was observed at the level just above the elbow joint. As expected the nerve diameter decreases from the most proximal to most distal level.

Table 1: Mean and standard deviation of different parameters measured in pig nerve specimen.

Nerve	Parameter	Level 1	Level 2	Level 3	Level 4	Level 5
Median (M)	Fascicle diameter	0.28±0.09 mm	0.27±0.08 mm	0.23±0.09 mm	0.24±0.09 mm	0.27±0.09 mm
Ulnar (U)	Fascicle diameter	0.26±0.06 mm	0.24±0.06 mm	0.23±0.08 mm	0.25±0.09 mm	0.24±0.09 mm
Median (M)	Cross-sectional area	0.067±0.04 mm^2	0.061±0.036 mm^2	0.048±0.033 mm^2	0.050±0.03 mm^2	0.061±0.04 mm^2
Ulnar (U)	Cross-sectional area	0.054±0.03 mm^2	0.048±0.024 mm^2	0.042±0.025 mm^2	0.035±0.03 mm^2	0.05±0.03 mm^2
Whole Nerve	Diameter	M,U 3.6±0.4mm	No measurements	M: 2.9±0.04mm U: 2.0±0.5mm	M: 2.2±0.6mm U: 1.8±0.5mm	No measurements

CONCLUSION: This study provided information on the number and size of fascicles in selected forelimb nerves at selected levels. New generation of neural interfaces, like the intrafascicular electrodes, will be used to selectively stimulate specific areas in nerve to activate specific muscles. This experiment may provide input to optimize electrode design.

WRIST MOTOR CONTROL AND COACTIVATION DURING A STEP-TRACKING TASK IN POST-STROKE HEMIPLEGIA AND UNIMPAIRED ADULTS: A PILOT STUDY

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AIM: Wrist step-tracking tasks have been used to evaluate normal motor control strategies and movement deficits in the limb ipsilateral to a stroke. This study compared motor control and muscle coactivation during a wrist step-tracking task in hemiplegic and unimpaired subjects and examined the relationship between these measures and functional activity.
METHODS: Six chronic stroke (mean age 63.3 (range 49-74)) and six unimpaired (61.5 (30-77)) subjects performed an arm activity test (Wolf motor function test) and a novel step-tracking task of random wrist flexion/extension movements using an instrumented rig and LED target display. Tracking performance was calculated using mean absolute error (MAE) for accuracy during the total task, path length (PL) and standard deviation (SD) of over- and under-shoot during the target phase (fig 1). Coactivation was quantified using correlation of rectified and smoothed flexor and extensor EMG (fig. 2) when extensor EMG was increasing; positive values ($r \geq 0.3$) signified coactivation. All data was normally distributed. Descriptive statistics and independent t-tests were used to estimate differences between hemiplegic and unimpaired controls and Pearson correlation coefficients to examine the relationship between impairment and activity variables.
RESULTS: Hemiplegic subjects were less good at tracking than unimpaired subjects (fig.3). Statistical significance was found in all the tracking measures (MAE p=0.029, PL p=0.001, SD p=0.026). Two subjects (#3&#5) who had abnormal coactivation (fig. 4) also had the poorest tracking and arm activity scores (#3 > #5). Statistically significant correlations were found between arm activity and tracking MAE (-0.93, 0.008) (fig. 3) and SD (-0.86, 0.03).
CONCLUSION: Step tracking performance was affected in the hemiplegic wrist in terms of accuracy during the task and size of over- and under-shoot and was strongly related to arm activity. Presence of coactivation in a small number of patients suggests it was not the main cause of arm activity limitations, but may be linked to poor tracking performance and activity.

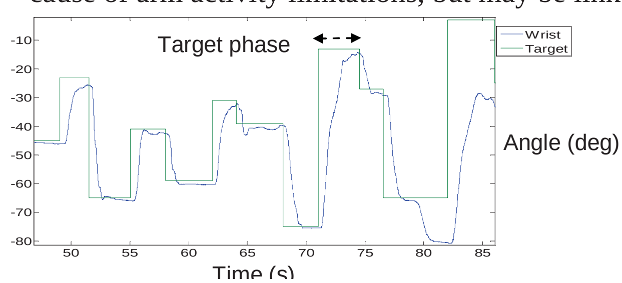

Figure 1 Example of impaired step tracking performance showing target and wrist movement

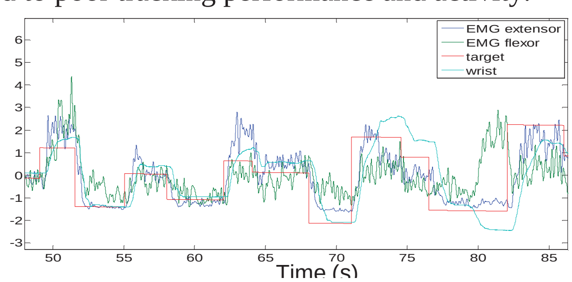

Figure 2 Example of impaired step tracking showing coactivation (EMG, target and wrist normalised)

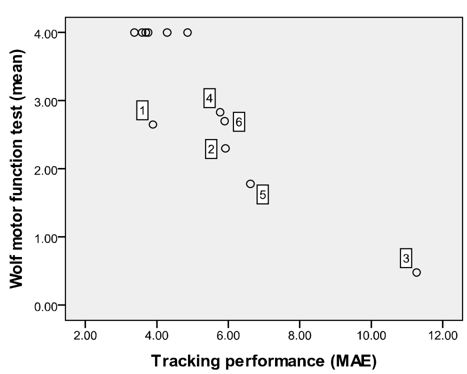

Figure 3 Correlation between the WMFT score and tracking performance

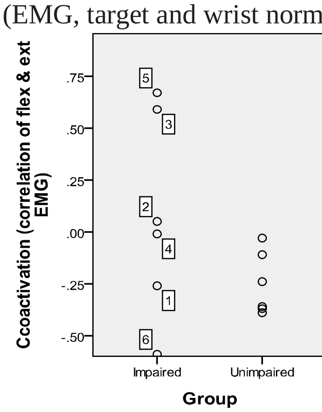

Figure 4 Dotplot showing coactivation in the stroke and unimpaired group

EFFECTS OF ELECTROSTIMULATION TRAINING ON RATE OF FORCE DEVELOPMENT AND MYOELECTRICAL MANIFESTATIONS OF FATIGUE IN CYSTIC FIBROSIS: PRELIMINARY RESULTS

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AIM: Cystic fibrosis (CF) is the most common genetic lethal disease among white population, predominantly affecting the lungs and the digestive system. However, peripheral muscle weakness is now recognized as one of the main systemic effects of CF and contributes to early fatigue, reduced functional capacity and thus to the alteration of quality of life. Passive training of specific locomotor muscle groups by means of neuromuscular electrical stimulation (NMES) might be better tolerated than whole body exercise in CF patients. We hypothesized that this strategy would be effective in improving muscle strength and delaying the onset of neuromuscular fatigue.
METHODS: This is a randomized controlled trial. The experiment started on January 2009. So far, we recruited 15 adults with CF (FEV_1 = 54 ± 13% predicted, BMI = 20 ± 2 kg/m^2) and 12 age-matched healthy controls. Each subject served as his own control and was assigned to usual rehabilitation (i.e. aerobic training [AT], 7 weeks) alone and to a AT+NMES program (7 weeks) in a random order. Each session of NMES program consisted of 5-min warm up period at 5-Hz (pulse width 400µs) + 22-min at 80-Hz for 6-s, alternated with a resting current of 5-HZ for 16-s). The electrical stimulation was applied on quadriceps muscle (both legs) and the intensity was set as the maximal tolerable amplitude by the patient. Maximal strength of the quadriceps (MVC), rate of force development (RFD), quadriceps endurance (time to exhaustion, 50% MVC) were measured before and after rehabilitation. Surface electromyography was recorded from the rectus femoris, vastus medialis and vastus lateralis during the endurance test. Neuromuscular fatigue was assessed using normalized median frequency value.
RESULTS: Six CF patients and 7 controls subjects have finished the entire protocol at this point (i.e. January 2010). All patients were able to complete the NMES program successfully. The AT+NMES program was associated with a trend toward (1) an increase of MVC and endurance time, (2) an increase of RFD in the late phase with no changes in the early phase and (3) a reduction of neuromuscular fatigue.
CONCLUSION: Our preliminary results suggest that NMES might improve muscle strength and endurance in CF patients. The analysis of changes in RFD and myoelectrical manifestations of fatigue will help to elucidate some of the underlying adaptation mechanisms. The end of the experiment is planned for April 2010.
ACKNOWLEDGEMENT: This study is financially supported by the French Cystic Fibrosis association “Vaincre La Mucoviscidose”

QUANTIFICATION OF THE LOAD ON THE LUMBAR SPINE AND DERIVATION OF PREVENTION MEASURES FOR PATIENT-HANDLING ACTIVITIES

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AIM: Typical work of caregivers like positioning patients in or at the bed or transferring them to a chair may result in high mechanical load on the lumbar spine, may furthermore be accompanied with low-back pain or result in degenerative lumbar diseases in the long run of occupational life of healthcare workers. The aim of the actual study was to quantify typical indicators of lumbar load – such as compressive and shear forces or bending and torsional moments of force at the lumbosacral disc – for several patient transfers, to compare different modes of task execution and to derive hints for biomechanically substantiated prevention measures.

METHODS: Via an optoelectronic position sensor system and several video cameras, the body movements of nurse and patient were captured in a laboratory setting. The action forces at nurse's hands were recorded via the re-action forces of a sensor-equipped bed, chair, floor and bathtub. Based on these posture-and-force measurements serving as input data, biomechanical calculations were performed to quantify lumbar load applying a 3-D dynamic simulation tool (The Dortmunder). The activities under study were carried out in a "conventional" and an "optimized" way; if possible, a third mode with supplementary usage of small aids (e.g. sliding board or mat) was applied. Patient's mobility varied between rather active and passive. Nearly 170 transfers were analyzed with respect to lumbar load, in total.

RESULTS: The predicted values representing the biomechanical load on the lumbar spine of a healthcare worker are often very high. The mean value for the lumbosacral-disc compressive force ranges between 1.8 and 6.9 kN, according to the 15 different tasks; the overall range is 1.6 to 8.9 kN. Estimating overload risk, the lumbar-load values were compared to corresponding age-and-gender specific recommendations for maximum loading of lumbar elements during occupational work (Dortmund Recommendations). As a result, lumbar load exceeds the recommended limits for most activities if the task is conventionally performed.

CONCLUSION: A considerable reduction of lumbar load can be achieved by applying an optimized task execution mode. When high-loading activities are performed by older persons, usage of small aids is vitally important to reduce lumbar load further. To limit the biomechanical overload risk for the healthcare worker during patient-transfer activities, design measures like a biomechanically optimized transfer technique and the application of small aids are highly recommended.

ACKNOWLEDGEMENT: (Berufsgenossenschaft für Gesundheitsdienst und Wohlfahrtspflege, BGW Hamburg, Germany) for financial funding, N. Wortmann and St. Kuhn (BGW Hamburg/Mainz, Germany) as well as B.-B. Beck and B. Wiedmann (Forum fBB, Hamburg, Germany) for very competent and helpful support.

EFFECTS OF MAXILAR AND MANDIBULAR OSTEOPOROSIS IN MASTICATORY CYCLES

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AIM: Osteoporosis is the most common human metabolic bone disease, with fractures and muscle loss as the most evident clinical manifestations. The purpose of this study was to analyze the electromyographic activity in mastication of individuals diagnosed with osteoporosis in the maxillary and mandibular areas, since the habits and conditions that cause the development of a generalized skeleton bone loss, including on face bones, can disturb the functional harmony of the stomatognathic system and, therefore, increase the chances of craniomandibular disorders.
METHODS: It was used 60 individuals of both sexes, with an average age of 23.0 ± 5 years, divided into two groups with 30 individuals each: 1. individuals with osteoporosis; 2. control individuals during the usual and unusual mastication. Surface electromyography was performed using five channels of the Myosystem-Br1 apparatus (DataHominis Ltd.), with simultaneous acquisition and common grounding to all channels. sEMG data were collected using surface differential electrodes (two Ag–AgCl bars, 10 × 2 × 1 mm, with 10 mm interelectrode distance, gain of 20, input impedance of 10 GΩ and common mode rejection ratio of 130 dB – Myosystem, São Paulo, Brazil). EMG signals were sampled by a 12-bit A/D converter board with a frequency of 2 kHz, and band-pass filtered at 0.01–1.5 kHz. The electromyographic signals of all the masticatory cycles were collected in three replicates of ten seconds, intercalated by two minutes of rest and, after this process, it was used the mean value. The masticatory efficiency of cycles between individuals was evaluated by the ensemble average of the electromyographic signal, and this value was obtained in microvolts/second, during the time. The values of ensemble average were normalized by the value of the electromyographic signal of maximum dental clenching, harvested by four seconds. The electromyographic means were tabulated and subjected to statistical analysis using ANOVA (SPSS 17.0).
RESULTS: The result of the Student t test indicated no significant differences ($p > 0.05$) between the normalized values of RMS obtained in masticatory cycles in both groups.
CONCLUSION: Based on the results of this research, it was possible to conclude that individuals with osteoporosis showed no performance and efficiency of masticatory cycles significantly lower when compared with control subjects during the proposal mastication, but they had in most clinical conditions electromyographic lowest averages for the masseter muscles and time. This result is very important, because it demonstrates the functionality of complex physiological process of mastication in individuals with osteoporosis at the bones that compose the face.
ACKNOWLEDGEMENT: This study was supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo.

THE EFFECT OF AGE IN HABITUAL CHEWING

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AIM: Chewing is one of the most important functions of the stomatognathic system. Masticatory mechanisms are flexible and, when disabled, are easily compensated. This can explain the considerable variation in the magnitude, duration and time of masticatory cycles in healthy subjects. The aim of this study was to analyze the electromyographic activity of left and right masseter and temporal muscles, in 177 individuals from 7 to 80 years, divided in five groups: I= 7-12, II= 13-20, III= 21-40, IV= 41-60 and V= 61-80 years to compare the habitual chewing in children, adolescents, young adults, adults and elderly, all nasal breathers, Angle's Class I, without parafunctional habits and symptoms of temporomandibular disorder.
METHODS: Surface electromyography was performed using five channels of the Myosystem-Br1 apparatus (DataHominis Ltd.), with simultaneous acquisition and common grounding to all channels. sEMG data were collected using surface differential electrodes (two Ag–AgCl bars, 10 × 2 × 1 mm, with 10 mm interelectrode distance, gain of 20, input impedance of 10 GΩ and common mode rejection ratio of 130 dB – Myosystem, São Paulo, Brazil). EMG signals were sampled by a 12-bit A/D converter board with a frequency of 2 kHz, and band-pass filtered at 0.01–1.5 kHz. The habitual chewing was verified through the electromyographic signal obtained during chewing of five peanuts and five raisins. The electromyographic signals of all the masticatory cycles were collected in three replicates of ten seconds, intercalated by two minutes of rest and, after this process, it was used the mean value. The masticatory efficiency of cycles between individuals was evaluated by the ensemble average of the electromyographic signal, and this value was obtained in microvolts/second, during the time. The values of ensemble average were normalized by the value of the electromyographic signal of maximum dental clenching, harvested by four seconds. The electromyographic means were tabulated and subjected to statistical analysis using ANOVA (SPSS 17.0).
RESULTS: There was significance ($p < 0.05$) for chewing with raisins and peanuts respectively: MD=[(I = 0.47 ± 0.03), (II=0.32 ± 0001), (III=0.44 ± 0.03), (IV=0.46 ± 0.03), (V=0.48 ± 0.07)]; ME=[(I=0.45 ± 0.02), (II=0.38 ± 0.05), (III=0.43 ± 0.37), (IV= 0.53 ± 0.06), (V=0.68 ± 0.08)] , TE=[(I = 0.54 ± 0.04), (II=0.45 ± 0.03), (III=0.50 ± 0.04), (IV=0.63 ± 0.05), (V=0.68 ± 0.13)]; MD=[(I=0.81 ± 0.06), (II=0.55 ± 0.03), (III=0.81 ± 0 , 07), (IV=0.69 ± 0.05), (V=0.64 ± 0.06)].
CONCLUSION: It was concluded that changes occurred in the patterns of activation of the masticatory muscles as times goes by, and the elderly individuals need a higher number of masticatory cycles to obtain the same masticatory performance of younger individuals.
ACKNOWLEDGEMENT: This study was supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo.

SURFACE EMG CONTAINS INFORMATION ON SMALL FORCE FLUCTUATIONS DURING FORCE-VARYING CONTRACTION

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AIM: When a subject varies force level substantially during isometric contraction, the high-frequency component of surface EMG, after being rectified and low-pass filtered, is highly correlated with force curves (Potvin & Brown 2004). However, it is unknown if the surface EMG contains information that may be correlated with small force fluctuations about the varying force. The purpose of this study was to examine if surface EMG during force-varying contraction contains information that is related to small force fluctuations.
METHODS: Eight healthy young adults (20-35 yrs) performed isometric contractions with the tibialis anterior muscle with the ankle joint in the neutral position. Subjects were instructed to increase dorsiflexion force linearly up to 30% of their maximal voluntary contraction force (MVC) and decrease it linearly back to zero in 12 s. The task was performed with visual feedback of force to match a triangular template with slopes of ± 5% MVC/s. Dorsiflexion force and surface EMG from the tibilalis anterior muscle (bipolar configuration with a 2-cm inter-electrode distance) were recorded at 1000 samples/s. EMG for the middle 8 s was processed in 2 ways: (1) to effectively utilize the high-frequency component, raw EMG was high-pass filtered at 300 Hz, rectified, and low-pass filtered at 2 Hz (HP-EMG); and (2) to extract the fluctuating (AC) component from the linearly changing HP-EMG, the linear trend was removed from the HP-EMG (ACHP-EMG). Corresponding force signals were processed in 3 ways: (1) to remove the electrical noise, force was low-pass filtered at 30 Hz (Force); (2) to extract the small fluctuating (AC) component, the linear trend was removed from Force (ACF); and (3) ACF was further differentiated (dACF/dt).
RESULTS: As expected, a clear peak was observed in the cross-correlation function (CCF) between HP-EMG and Force (0.95-0.98). In comparison, the peak in CCF between ACHP-EMG and ACF was not present (n = 1) or significantly smaller (0.00-0.30, $P < 0.0005$), indicating ACHP-EMG may not provide direct information on small force fluctuations. In contrast, there was a clear and significant ($P < 0.0001$) peak in CCF between ACHP-EMG and dACF/dt in all subjects (0.25-0.44).
CONCLUSION: The results suggest that high-frequency component of surface EMG contains information for both the varying level and small fluctuations of muscle force during force-varying contractions. The latter information is the first derivative of force fluctuations.
ACKNOWLEDGEMENT: Supported in part by Physical Fitness Research Institute MEIJI YASUDA Life Foundation of Health and Welfare.

ENHANCED PHYSIOLOGICAL TREMOR DETERIORATES PLANTAR FLEXOR TORQUE STEADINESS AFTER BED REST

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AIM: The study evaluated the effectiveness of resistance training and vibration-augmented resistance training to preserve plantar flexor torque steadiness after 60 days of bed rest (BR).
METHODS: The 2nd Berlin BedRest Study incorporated adult male subjects that underwent either BR only (CTR, n = 8), BR plus resistance training (RE, n = 7) or BR plus vibration-augmented resistance training (RVE, n = 7). Before and following BR, subjects performed steady isometric plantar flexor contractions at normalized submaximal intensities (20, 40, 60 and 80% of maximum voluntary contraction, MVC).
RESULTS: Following BR, torque fluctuations (assessed as coefficient of variation, COV) increased ~329% and ~209% for CTR and RE, respectively ($P < 0.01$), whereas COV remained unchanged for RVE. Spectral analysis revealed the increase in COV for CTR to be associated with the amplification of rhythmic torque oscillations dominantly between 6 and 12 Hz following BR (Figure 1), causing a significant shift in the spectral distribution of torque fluctuations ($P < 0.05$). RE showed a tendency towards such a spectral shift ($P < 0.1$), whereas RVE did not. Agonistic EMG amplitude increased ~10% across groups ($P < 0.05$) whereas antagonistic EMG amplitude remained unaltered following BR. Spinal excitability (H-reflex amplitude) declined collectively ~19% ($P < 0.01$) and was uncorrelated with the changes in COV.
CONCLUSION: The present findings suggest that BR deteriorated plantar flexor torque steadiness primarily due to the origin/amplification of oscillations in the 6-12 Hz band, indicating enhanced physiological tremor. The addition of vibration exposure to resistance training improved the efficacy of resistance training to preserve plantar flexor torque steadiness, but through other mechanisms than modulations in spinal excitability.

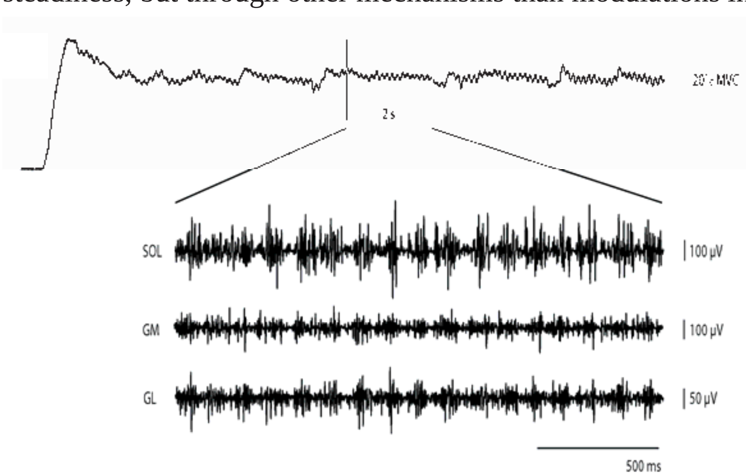

Figure 1. This graph represents the rhythmic torque and electromyographic oscillations that emerged in the inactive control group (CTR) after 60 days of bed rest. SOL, soleus; GM, medial gastrocnemius; GL, lateral gastrocnemius.

SURFACE EMG ACTIVITY PATTERNS OF MASTICATORY MUSCLES

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AIM: This study evaluated the sEMG activity of the bilateral masseter and temporalis muscles in Brazilian children, youth, adults, and elderly people at rest and at different jaw postural conditions in order to establish normality standards for the sEMG activity of masticatory muscles in relation to age.
METHODS: 250 individuals were evaluated and 177 were included in the final sample according to the inclusion criteria. All volunteers were fully dentate (except for Group I - mixed dentition, caucasian, aged 7 to 80 years, and divided into five groups: I (7-12 years), II (13-20 years), III (21-40 years), IV (41-60 years), and V (61-80 years). Except for Group V, which comprised nine women and eight men, all groups were equally divided in respect to gender (20 M/ 20 F). All subjects had normal occlusion, no parafunctional habits and had to be free of signs and symptoms of any dysfunction of the masticatory system. Surface electromyography was performed using five channels of the Myosystem-Br1 apparatus (DataHominis Ltd.), with simultaneous acquisition and common grounding to all channels. sEMG data were collected using surface differential electrodes (two Ag–AgCl bars, 10 × 2 × 1 mm, with 10 mm interelectrode distance, gain of 20, input impedance of 10 GΩ and common mode rejection ratio of 130 dB – Myosystem, São Paulo, Brazil). EMG signals were sampled by a 12-bit A/D converter board with a frequency of 2 kHz, and band-pass filtered at 0.01–1.5 kHz. Raw sEMG data were digitally filtered at frequency bandwidth of 10–500 Hz and root mean squares (RMS) were calculated. Three maximal voluntary isometric dental contractions (MVCs) were performed for each muscle to normalize the sEMG data (4s). sEMG activity was recorded at rest, protrusion, left and right laterality, and maximal clenching in the intercuspal position, each recording lasted 10 seconds. Analyses of variance (ANOVA) were used to compare the groups' EMG recordings and the level of statistical significance was set at $p<0.05$ (Table 1).
RESULTS: The children group had higher EMG activity recordings for all clinical situations, while the young people group displayed lower muscular activity. As age increases from youth to adults and from adults to elderly, a clear decrease in EMG activity was observed, confirming that many changes occur in the stomatognathic system as a function of age.
CONCLUSION: Considerably different patterns of muscle activation were found across ages, with greater electromyographic activity in children and youth, and decreasing from adults to aged people.

ACKNOWLEDGEMENT
This study was supported by the Funda o de Amparo Pesquisa do Estado de S o Paulo (FAPESP – process # 2006/60965-6).

Table 1. Normalized sEMG data of bilateral masseter and temporalis muscles for Groups I-V in the following clinical conditions: rest, right and left laterality, protrusion, and maximal clenching.

		Group					
Clinical Condition	Muscle	I	II	III	IV	V	Significance
Rest	RM	0.10 ± 0.01	0.04 ± 0.03	0.07 ± 0.009	0.06 ± 0.08	0.05 ± 0.08	*
	LM	0.10 ± 0.01	0.05± 0.05	0.08 ± 0.008	0.10 ± 0.01	0.06 ± 0.01	*
	RT	0.10 ± 0.01	0.05± 0.004	0.10 ± 0.01	0.11 ± 0.01	0.08 ± 0.01	*
	LT	0.10 ± 0.01	0.05± 0.004	0.11 ± 0.01	0.11 ± 0.01	0.08 ± 0.01	*
Right laterality	RM	0.15 ± 0.02	0.09 ± 0.007	0.13 ± 0.01	0.14 ± 0.01	0.16 ± 0.02	*
	LM	0.18 ± 0.01	0.10 ± 0.01	0.12 ± 0.01	0.14 ± 0.02	0.15 ± 0.02	*
	RT	0.15 ± 0.02	0.09 ± 0.007	0.13 ± 0.01	0.14 ± 0.01	0.16 ± 0.02	
	LT	0.11 ± 0.01	0.05 ± 0.005	0.11 ± 0.01	0.10 ± 0.01	0.08 ± 0.01	*
Left laterality	RM	0.18 ± 0.02	0.08± 0.01	0.11 ± 0.01	0.13 ± 0.02	0.14 ± 0.02	*
	LM	0.15 ± 0.03	0.06± 0.006	0.10 ± 0.01	0.10 ± 0.01	0.11 ± 0.02	*
	RT	0.11 ± 0.02	0.05± 0.005	0.11 ± 0.01	0.10 ± 0.01	0.07 ± 0.007	
	LT	0.14 ± 0.01	0.07± 0.01	0.14 ± 0.01	0.14 ± 0.02	0.11 ± 0.01	*
Protrusion	RM	0.27 ± 0.03	0.15 ± 0.02	0.16 ± 0.02	0.20 ± 0.03	0.17 ± 0.03	*
	LM	0.24 ± 0.02	0.14 ± 0.01	0.18 ± 0.02	0.18 ± 0.03	0.18 ± 0.02	
	RT	0.11 ± 0.01	0.07 ± 0.01	0.11 ± 0.01	0.10 ± 0.01	0.09 ± 0.02	
	LT	0.10 ± 0.01	0.06 ± 0.009	0.11 ± 0.01	0.12 ± 0.01	0.09 ± 0.01	*
Maximal clenching	RM	1.07 ± 0.08	0.78 ± 0.04	0.74 ± 0.04	0.67 ± 0.04	0.71 ± 0.06	*
	LM	0.99 ± 0.07	0.81 ± 0.04	0.84 ± 0.07	0.66 ± 0.04	0.79 ± 0.06	*
	RT	1.14 ± 0.09	0.93 ± 0.03	1.03 ± 0.08	0.84 ± 0.04	0.87 ± 0.05	*
	LT	1.23 ± 0.12	0.91 ± 0.04	0.95 ± 0.06	0.83 ± 0.05	0.80 ± 0.05	*

* significant for $p<0.05$

ASSESSING MUSCLE INACTIVATION: NERVE VS. MUSCLE STIMULATION

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AIM: The extent of muscle inactivation is usually measured with the twitch interpolation technique, which consists in the application of one or more electrical stimuli on a maximal voluntary contraction (MVC); the higher the superimposed force, the higher the inactivation level. The aim of the present work was to compare over the muscle stimulation (referred to as muscle stimulation) vs. femoral nerve stimulation to assess quadriceps muscle inactivation over a range of contraction levels.
METHODS: 14 healthy subjects (8 men, 6 women; 27 ± 5 yr) were tested. Supramaximal paired stimuli (doublet at 100 Hz) were delivered to the femoral nerve or to the quadriceps muscle belly at rest and during voluntary contractions ranging from 20 to 100% of MVC, and the amplitude of the superimposed doublet was quantified to investigate inactivation. The level of discomfort associated with both stimulation procedures was assessed via a visual analogue scale (VAS).
RESULTS: The size of the superimposed doublet was almost identical for the two stimulation modalities in the range of 60 to 100% MVC (14 ± 5 Nm vs. 15 ± 6 Nm respectively for muscle and nerve stimulation at 100% MVC, P>0.05, see Fig. 1). VAS discomfort scores for doublet responses were higher for nerve than for muscle stimulation (25.1%; P<0.05) despite lower optimal stimulation intensity (71 ± 19 mA vs. 100 ± 0 mA for nerve and muscle stimulation, respectively, P<0.001).
CONCLUSION: Present results legitimate the use of muscle stimulation for twitch interpolation applications for strong voluntary contractions (≥60% MVC). These data could be valuable to clinicians who may want to use the twitch interpolation technique for evaluating muscle inactivation.

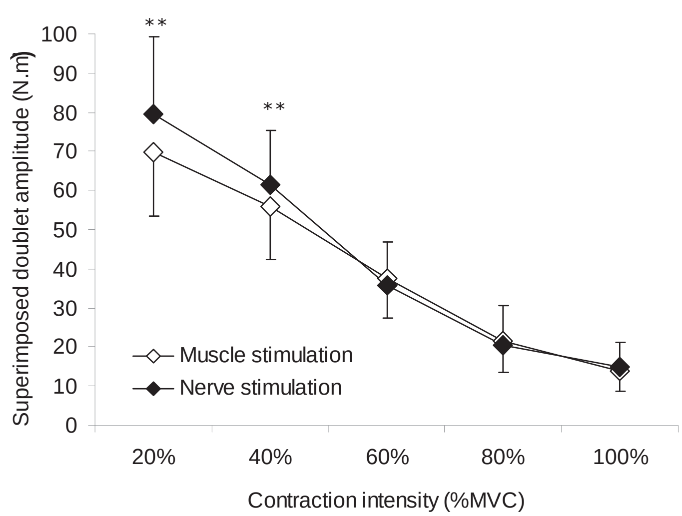

Figure 1: Superimposed doublet amplitude (mean ± SD) at different voluntary contraction levels for muscle and nerve stimulation. **P < 0.01 different between muscle and nerve stimulation.

ANTIDEPRESSIVE AND ANTIPSYCHOTIC DRUGS EFFECT ON MASTICATORY MUSCLES IN INDIVIDUALS WITH SCHIZOPHRENIA AND AFFECTIVE DISORDERS COMPARED TO CONTROL GROUP

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AIM: Drugs used in psychiatric disorders treatment are influent on muscular system as a whole. The use of antidepressant and antipsychotic medications causes chronic and acute motor collateral effects, including Parkinsonism, akathisia and dyskinesia, characterized by involuntary buccofacial movements, that appear on around 20% treated patients.
METHODS: The aim of this study was to compare the sEMG activity of the right and left temporalis and masseter muscles during rest position and postural movements (10s), between 20 individuals with schizophrenia (GI), 20 individuals with affective disorders (GII) and 40 controls (GIII). The sEMG analysis was performed using a MyoSystem-BR1 electromyographer with differential active electrodes (silver bars 10 mm apart, 10 mm long, 2 mm wide, 20x gain, input impedance 10 GΩ and 130 dB common mode rejection ratio). Surface differential active electrodes were placed on the skin, bilaterally on both masseter muscles and on the anterior portion of the temporalis. A ground electrode was also used and fixed on the skin over the sternum region. The sEMG signals were analogically amplified with a gain of 1000x, filtered by a pass-band of 0.01-1.5KHz and sampled by a 12-bit A/D converter with a 2 KHz sampling rate. The data collected were normalized by maximum voluntary contraction (MVC), and the results were statistically analyzed using the ANOVA test (SPSS- 17.0- Chicago) during the comparison between groups ($p<0.05$).
RESULTS: The psychiatric individuals presented higher EMG activity than control individuals (Table 1) during all positions tested in this study, including rest. During EMG data comparison there was a statistical significance between groups for all conditions ($p<0.05$).
CONCLUSIONS: The data allow us to conclude that the mental health medication had a stronger influence on the masticatory muscles activity, causing an exaggerated recruitment of muscle fibers to perform a static and dynamic activity. The results may provide valuable data to be considered when choosing one of these treatments for psychiatric patients, which will improve their quality of life.
ACKNOWLEDGEMENTS: Financial support from FAPESP

Table 1: Normalized sEMG activity of the masseter and temporalis muscles according the clinical conditions. All data presented statistical significance between the groups ($p<0.05$).

Group	**Masseter**		**Temporalis**	
	Right	**Left**	**Right**	**Left**
Rest GI	0.11	0.14	0.21	0.28
Rest GII	0.25	0.32	0.31	0.25
Rest GIII	0.07	0.07	0.09	0.08
Right Laterality GI	0.18	0.18	0.22	0.23
Right Laterality GII	0.37	0.15	0.39	0.21
Right Laterality GIII	0.08	0.09	0.12	0.08
Left Laterality GI	0.12	0.15	0.21	0.19
Left Laterality GII	0.38	0.47	0.31	0.35
Left Laterality GIII	0.11	0.07	0.08	0.09
Protrusion GI	0.18	0.27	0.33	0.26
Protrusion GII	0.74	0.46	0.29	0.13
Protrusion GIII	0.17	0.15	0.09	0.08

BIOFEEDBACK IS MORE EFFECTIVE THAN ACTIVE EXERCISE AND PASSIVE PHYSIOTHERAPY IN RE-EDUCATING TRAPEZIUS MUSCLE ACTIVITY IN COMPUTER USERS WITH NECK PAIN

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AIM: Biofeedback has been shown to be able to reduce trapezius muscle activity in office workers in past research. The present study aimed to compare the effectiveness of biofeedback with active exercises and passive therapeutic treatment in improving trapezius motor control during computer work. By examining the differential effects of these interventions, the results provide further understanding on the motor control mechanisms contributing to work-related neck pain in office workers.
METHODS: The study is a randomized clinical trial (RCT) with 4 groups: biofeedback, active exercise, passive treatment and control group. Altogether 72 subjects (mean age =33.3±9.7 yrs) were recruited into the study and 60 subjects (20 males, 40 females) completed the intervention programs and all the pre- and post-intervention evaluations. Subjects were randomly assigned into the 4 groups with 15 subjects in each group, and the groups were matched in gender and age. All subjects must have had a past and present history of computer-related neck and shoulder symptoms and were daily computer users of at least 2 hours or more. Surface electromyography (sEMG) were assessed of upper trapezius (UT) and cervical erector spinae (CES) were assessed at pre- and post-intervention, when subjects performed simulated typing tasks using a standardized computer workstation. In the biofeedback group, subjects were instructed to use a portable biofeedback machine on bilateral upper trapezius for 1-2 hours daily while performing computer work. In the active exercise group they were instructed to carry out a standardized exercise program daily on their own. The passive treatment group would receive standardized physiotherapy treatment with interferential therapy and hot pack twice a week. The control group was given a standard instruction booklet about principles of office ergonomics. CES and UT muscle activities were compared within and between groups in terms of Amplitude Probability Distribution Function (APDF). Other outcome measures included pain level and neck disability index (NDI) scores.
RESULTS: All three intervention groups showed significantly decreased pain and NDI scores after the interventions. The 10^{th}%, 50^{th}% and 90^{th}% APDF during typing showed significant pre- and post- intervention differences in all three groups compared to control group. The 50^{th}% APDF showed significantly greater reduction in UT activity in the biofeedback group compared to active exercise and passive treatment at post-intervention. CONCLUSION: The present study showed that biofeedback is more effective than active exercises and passive treatment in re-educating upper trapezius activity, and this is associated with greater reduction in neck pain. These results confirmed the important contribution of altered motor control in the development of musculoskeletal disorders.

Table 1: Comparisons of Pre- and Post-intervention 50^{th}%APDF of UT activity (μV).

Group	**Pre**	**Post**	**Pre**	**Post**
Biofeedback	15.16(4.36)	6.29(1.66)	15.33(3.42)	7.00(1.44)
Active exercise	14.86(6.87)	10.12(3.95)	13.47(7.33)	10.22(4.18)
Passive treatment	14.78(8.27)	10.48(4.57)	16.83(10.31)	10.63(4.69)
Control	16.64(7.70)	16.68(5.58)	15.95(6.90)	15.62(5.75)

NEUROMUSCULAR COORDINATION IN TEMPOROMANDIBULAR DISORDERS AND CONTROL SUBJECTS

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AIM: The neuromuscular coordination is important parameters in the stomatognathic system evaluation. The objective of the study was to analyze the neuromuscular coordination of the temporomandibular disorders (TMD) patient's and a control group by electromyographic standardized indices.
METHODS: Twenty subjects were randomly selected of a group with long lasting associated articular and muscular TMD (TMDG - mean age = 35 years). Twenty healthy subjects (mean age = 22 years), free from periodontal problems, TMD, and with full permanent dentition (28 teeth at least), represented the control group (CG). The analog EMG signal was amplified (gain 150, bandwith 0-10Hz, peak-to-peak, input range from 0 to 2000 µVs) using differential amplifiers with a high common mode rejection ratio (CMRR = 105 dB in the range 0-60Hz, input impedance 10GΩ), digitized (12 b resolution, 2230Hz A/D sampling frequency), and digitally filtered (high-pass filter set a 30 HZ, low-pass filter set at 400 Hz, band-stop for common 50-60 Hz noise). The signals were averaged over 25 ms, with muscle activity assessed as the root mean square (r.m.s.) of the amplitude (µV). EMG signals were recorded during: maximum voluntary dental clench (MVC) with cotton rolls interposed between the first molars ⁄ second premolars (10-mm-thick cotton rolls – Roeko Luna) and maximum voluntary teeth clench. The EMG potentials recorded during the MVC tests were expressed as per cent of the mean potential recorded during the MVC on the cotton rolls (unit: µV/µV x 100). The indices calculations were made with the standardized potentials to determine muscular symmetry (left and right side, percentage overlapping coefficient, POC), potential lateral displacing components (unbalanced contractile activities of contralateral masseter and temporalis muscles, TC) and relative activity (most prevalent pair of masticatory muscles, ATTIV).
RESULTS The TMDG presented asymmetry between left and right muscle temporal and masseter (POC Temporal = 78.64±10.48%), (POC Masseter = 77.11±11.18%), unbalanced contractile activities of contralateral masseter and temporalis muscles - lateral displacing force (TC = 14.58±8.06%), and the temporalis were the prevalent pair of masticatory muscles (ATTIV = -15.09±17.94%). The CG show normal indices values, i.e, neuromuscular coordination (POC Temporal = 88.23±1.14%, POC Masseter = 87.0±1.52%, TC = 8.95±1.10%, ATTIV = 0.02±13.63%). There were significant differences between groups for all indices ($p < 0.01$).
CONCLUSION: The results confirm that subjects with TMD present greater imbalance between the ipsi and contralateral jaw muscles.
ACKNOWLEDGEMENT: This work was supported by and Conselho Nacional de Pesquisa - CNPq, Process N. 300950/2007-1. and N. 470174/2008-0.

OROFACIAL MYOFUNCTIONAL THERAPY IN THE NEUROMUSCULAR COORDINATION OF TEMPOROMANDIBULAR DISORDERS PATIENT'S

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AIM: The objective of the study was to assess by electromyographic standardized indices the TMD treatment outcomes based on the orofacial myofunctional therapy (OMT).
METHODS: Ten subjects were randomly selected of a group with long lasting associated articular and muscular TMD (mean age = 35 years) for OMT. Nine accomplished the treatment (TG). Twenty healthy subjects (mean age = 22 years) represented the control group (CG). The diagnosis was based on the RDC/TMD. Electromyography of the right and left masseter and temporalis muscles was performed using a computerized instrument (Freely, De Götzen srl; Legano, Milano, Italy). The analog EMG signal was amplified (gain 150, bandwith 0-10Hz, peak-to-peak, input range from 0 to 2000 μVs) using differential amplifiers with a high common mode rejection ratio (CMRR = 105 dB in the range 0-60Hz, input impedance 10GΩ), digitized (12 b resolution, 2230Hz A/D sampling frequency), and digitally filtered (high-pass filter set a 30 HZ, low-pass filter set at 400 Hz, band-stop for common 50-60 Hz noise). The signals were averaged over 25 ms, with muscle activity assessed as the root mean square (r.m.s.) of the amplitude (μV). EMG signals were recorded during: maximum voluntary dental clench (MVC) with cotton rolls interposed between the first molars⁄second premolars and MVC. The EMG potentials recorded during the MVC tests were expressed as per cent of the mean potential recorded during the MVC on the cotton rolls (unit: μV/μV x 100). The indices calculations were made with the standardized potentials to determine muscular symmetry (left and right side, percentage overlapping coefficient, POC), potential lateral displacing components (unbalanced contractile activities of contralateral masseter and temporalis muscles, TC). OMT was planned to favoring pain relief, mandibular posture and mobility without deviations, symmetry between muscle pairs, coordination of the muscles of the stomatognathic system, as well as equilibration of the stomatognathic functions in a manner compatible with occlusion (treatment duration = 120 days). The comparisons between groups and phases were calculated by Student t-Test, respectively for unpaired and paired samples.
RESULTS: The CG presented mean values of POC Temporal (88.11±1.45), POC Masseter (87.17±1.60), TC (8.79±1.2). The mean values of the TG were, respectively, in diagnostic (DP) and final phase (FP): POC Temporal (80.49±13.0 / 85.29±5.86), POC Masseter (80.31±10.84 / 84.42±3.91) and TC (13.53±9.36 / 11.07±4.36). There were significant differences between CG and TG in both DP and FP ($p< 0.05$). There were no statistically significant differences between phases of the TG ($p > 0.05$).
CONCLUSION The CG presented mean values of EMG indices according to normality. During phase F the TG presented mean values lower than normal. During the F phase there were improvement of mean values of POC Temporal, POC Masseter and TC, indicating respectively, lower asymmetry between right and left muscle pairs and better balanced contractile activities of contralateral masseter and temporalis muscles (lower lateral displacing force). Although the changes were not sufficient to promote difference significant, the OMT may improve neuromuscular coordination.

INTRODUCTION TO EMG DECOMPOSITION

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AIM: EMG decomposition is one of a very few methods for studying the behavior, organization, and integrity of individual human motor units in vivo. This workshop will provide a practical introduction to EMG decomposition, focusing on intramuscular (needle or fine-wire) EMG signals, but considering surface signals as well.

METHODS: This lecture will discuss issues related to signal acquisition, computer-aided decomposition, best practices for achieving reliable results, and accuracy assessment. EMG decomposition involves recording multi-unit signals and then sorting out the discharges of the different active motor units based on their distinctive shapes. EMG decomposition makes it possible to study the joint firing behavior and comparative organization of groups of motor units, thus providing a fuller picture of neural control and muscle organization than can be obtained by studying motor units one at a time. Decomposition is not necessarily easy, however. A serious commitment, and often a lot of work, are required on the part the investigator to ensure that the results are full and accurate. One resource is EMGlab (www.emglab.net), a free, open-source program for viewing and decomposing EMG signals. EMGlab is able to read signals in a variety of different formats. It provides an automatic decomposition algorithm and a versatile graphical interface for manually inspecting and editing the results.

CONCLUSION: When used correctly, EMG decomposition can provide precise information about the recruitment and joint firing behavior of groups of motor units and about the architectural organization of motor units in the muscle.

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MOTOR ADAPTATION IN MUSCULOSKELETAL PAIN

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AIM: The clinical importance of musculoskeletal pain is obvious and it is evident that it impairs the daily activities. This presentation will focus on how deep-tissue pain interacts with the motor control system. Over the past decade it has become evident that muscle pain interferes with motor control strategies and different patterns of interaction are reported during different contraction types and resting conditions. A reorganised motor control system with functional adaptations of the muscle co-ordination and strategies is a key factor in musculoskeletal pain conditions; its relevance in the transition from acute pain to chronic pain is most likely underestimated.
METHODS: The interaction between muscle pain and motor control depends on the specific motor task. Muscle pain causes no increase in muscle activity assessed by electromyography at rest, reduce maximal voluntary contraction levels, and shorten endurance time during sub-maximal contractions. Moreover, muscle pain causes an adaptive change in the co-ordination during dynamic exercises. In some cases increased muscle activity reflecting reorganised muscle co-ordination and strategy is also a component of the functional adaption to muscle pain. Motor unit recordings have also shown the strong interaction between pain and motor control. Finally, reflex methodologies provide evidence for changes in motor neuronal excitability illustrating mainly inhibitory effects of pain at spinal and cortical motor neurons.
CONCLUSION: The ‘vicious cycle’ or hyperactivity hypothesis is in general not supported by the above findings. An adaptive model is more relevant predicting reduced agonistic muscle activity eventually advanced by changed antagonistic muscle activity. The quantitative motor control assessment procedures provide additional clinical information and give further support for optimising treatment and prevention procedures for musculoskeletal pain.

GLOBAL POSTURAL REEDUCATION IN INDIVIDUALS WITH TEMPOROMANDIBULAR DISORDERS (TMD) AND POSTURAL DEVIATION: ELECTROMYOGRAPHY ANALYSIS

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AIM: To verify the electromyographic activity of the masticatory and cervical muscles in individuals with TMD and postural deviation, before and after Global Postural Reeducation (GPR).
METHODS: 20 participants were selected, 17 women and 3 men, mean age of 27.8 years old, with TMD diagnosis by means of RDC / TMD instrument associated to postural deviation. The EMG recordings were acquired on the masseter, temporal (anterior part), sternocleidomastoideus and trapezius (upper fibers) muscles, bilaterally, at rest, during postural alignment, maximum intercuspation, isometric contraction of the SCM and the trapezius muscles. The signals were acquired and processed in RMS (root mean squares) After 10 sessions of GPR, this evaluation was repeated. The data analysis was accomplished by the Wilcoxon test and the T paired test.
RESULTS: There was significant reduction of RMS values at rest (table 1) , during postural alignment and isometry in all studied muscles. It was observed before and after GPR predominance of the anterior temporal muscles activity over the masseter muscles, which characterizes the assynergic pattern between them.
CONCLUSION: Therefore, this study contributes with objective evidences that the GPR in TMD patients was effective in the postural re-alignment, since the EMG activity of the masticatory and cervical muscles at the rest and alignment postural reduced. It was obtained EMG activity next to the resting levels, indicating a better muscle balance. The muscular assynergy between temporal and masseter muscles was not totally corrected, which probably requires a localized intervention.

Table 1: Mean and Standard-Deviation of RMS values (µV)of Masticatory And Cervical Muscles Activity at rest before and after GPR.

MUSCLES	BEFORE GPR	AFTER GPR	p
	Mean ± SD	Mean ± SD	
Masseter Right	5,56 ± 1,31	3,65 ± 1,26	0,00014*
Masseter Left	5,81 ± 1,95	3,28 ± 1,07	0,00008*
Temporal Right	6,90 ± 1,79	5,47 ± 1,29	0,00576*
Temporal Left	8,00 ± 2,42	5,22 ± 1,63	0,00001*
Sternocleidomastoideus right	6,02 ± 1,11	4,43 ± 0,94	0,00021*
Sternocleidomastoideus left	5,95 ± 1,14	4,43 ± 1,79	0,00518*
Trapezius right	7,90 ± 4,16	5,15 ± 2,26	0,00360*
Trapezius left	8,36 ± 4,30	5,97 ± 1,98	0,00254*

*Significance level $p< 0,05$

PERIODIC ACTIVATION OF THE TRAPEZIUS MUSCLE DURING A REPETITIVE TAPPING TASK

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AIM: In this study the pattern of trapezius muscle activation when repetitively tapping a key with a finger is described. The objectives were to 1) determine whether the trapezius is active during supported key tapping, 2) determine whether trapezius activity is cross-correlated with forearm muscle activity and 3) determine if trapezius activity depends on key make.
METHODS: Thirteen right-handed subjects (seven women and six men; mean age was 29.7 ± 11.4 years) participated in the experiment. Surface EMG of the finger extensor and flexor muscles and the m. trapezius, as well as the key on-off signal, were recorded while the subject performed ten two minute sessions of key-tapping at 4Hz using a different key make (different force displacement characteristics) each time. The linear envelopes obtained from each channel were cut from on-to-on using the onset signal of the key-tap and subsequently time normalized. The outliers, defined as the 10th and 90th percentile from the range of trapezius activity for each on-to-on cycle, were filtered. 1) Effect size between mean range over the on-to-on cycles and maximal standard deviation was calculated to determine if a burst of trapezius activation was present. 2) To check if there was a difference in the time point of the activity bursts between the forearm muscles and the TR muscle during the on-to-on cycle cross-correlation was used. For each person the mean and standard deviation of the maximal correlation between forearm muscles and trapezius were determined. 3) Mixed models were used to calculate the effects of the different persons and keys on the cross-correlation parameter.
RESULTS: 1) Results showed a burst of activation in the trapezius muscle during the on-to-on cycle and the calculated effect size was ≥0.5 in 67% of the cases. 2) Cross-correlations between forearm and trapezius activity was between 0.75 and 0.98 (mean 0.93 ±0.05) for both extensor and flexor muscles. 3) Trapezius activity did not depend on key make for flexor muscle (P=0.10, F=1.71) nor for extensor muscle (P=0.11, F=1.66).
CONCLUSION: Trapezius muscle was active during supported key tapping and its activity was correlated with forearm muscles activity. The key-make did not significantly affect trapezius activity.

Table 1: Key force-displacement characteristics and labels

Key-name	40p	60p	80p	100p	120p	1mm	2mm	3mm	4mm	5mm
Make-force [N]	0.39	0.59	0.78	0.98	1.18	0.59	0.59	0.59	0.59	0.59
Key displacement [mm]	3	3	3	3	3	1	2	3	4	5

APPLICATION OF SINGULAR SPECTRUM-BASED CHANGE-POINT ANALYSIS TO EMG ONSET DETECTION

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AIM: While many approaches have been proposed to identify the signal onset in EMG recordings, there is no standardized method for performing this task. Here, we propose to use a change-point detection procedure based on singular spectrum analysis to determine the onset of EMG signals.
METHODS: This method is suitable for automated real-time implementation, can be applied directly to the raw signal, and does not require any prior knowledge of the EMG signal's properties. The algorithm proposed by Moskvina et.al. (2003) was applied to EMG segments recorded from wrist and trunk muscles. Wrist EMG data was collected from 9 Parkinson's disease patients with and without tremor, while trunk EMG data was collected from 13 healthy able-bodied individuals. Along with the change-point detection analysis, two threshold-based onset detection methods were applied, as well as visual estimates of the EMG onset by trained practitioners.
RESULTS: In the case of wrist EMG data without tremor, the change-point analysis showed comparable or superior frequency and quality of detection results, as compared to other automatic detection methods. In the case of wrist EMG data with tremor and trunk EMG data, performance suffered because other changes occurring in these signals caused larger changes in the detection statistic than the changes caused by the initial muscle activation, suggesting that additional criteria are needed to identify the onset from the detection statistic other than its magnitude alone.
CONCLUSION: The change-point detection should provide an effective EMG-onset detection method suitable for automated real-time implementation.

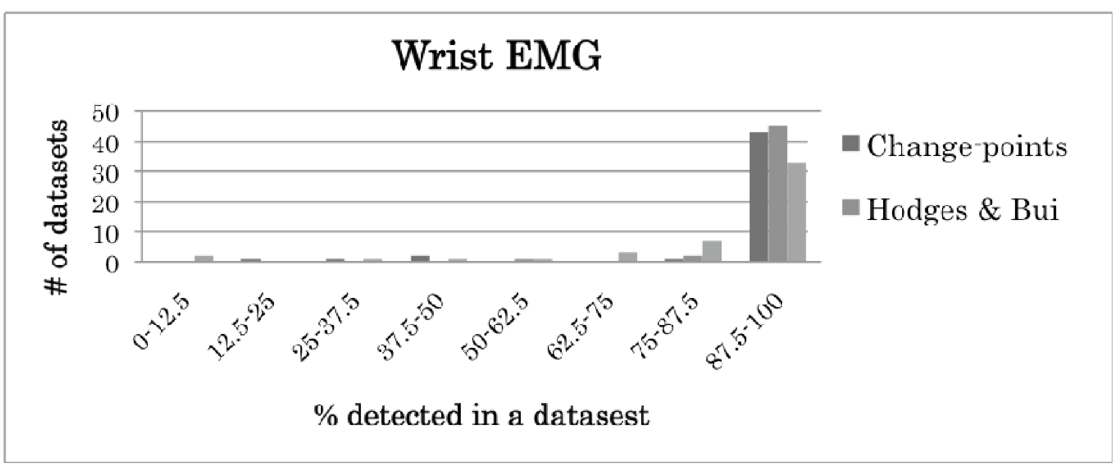

Figure 1: Histogram of % Successful Onset Detection in Wrist EMG for Different Computer Methods.

DECOMPOSING THE ANKLE TORQUE DURING QUIET STANDING INTO ACTIVE AND PASSIVE COMPONENTS USING EMG

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AIM: Recently, we proposed a method by which we can decompose the exerted ankle joint torque into a torque component controlled by the neural system (torque output from the contractile element, active torque) and one controlled by mechanical mechanisms (torque output from the parallel elastic element, passive torque) [Vette et al. IEEE TNSRE, in press]. The purpose of the present study was to validate this methodology via a systematic simulation study.
METHODS: <Decomposition Method> The decomposition is based on a model (Figure 1) that uses two input signals: EMG and the angular displacement of the body during quiet standing. The measured EMG and angular displacement are fed into the model, and the model output torque is matched with the experimentally measured torque using a parameter optimization technique. Using this optimization procedure, the intrinsic stiffness of the ankle joint complex and the properties of the neural torque generation process can be identified. <Simulation Study> We simulated human quiet standing using the model proposed in our previous study [Masani et al. J Neurophysiol 100: 1465-, 2008]. The neural controller was modeled as a proportional-derivative controller. First, we identified parameter combinations that can stabilize the entire system using Nyquist stability analysis. Body sway during quiet standing was simulated by injecting noise into the simulation model. The noise was injected at three locations, representing motor, sensory, and mechanical noise. Additionally, three different noise properties were tested. After the simulation, the decomposition analysis was applied for the simulated time series. To validate the decomposition analysis, the identified model parameters were finally compared with the actual parameters used in the simulation.
RESULTS and CONCLUSION: The identified model parameters were identical to the actual parameters for all simulation scenarios (highly correlated and on the line of identity). Thus, we conclude that the decomposition method is validated. It can be used to investigate the active and passive torque contributions to the control of quiet standing – for different ages and neurological impairments – without applying external perturbations.

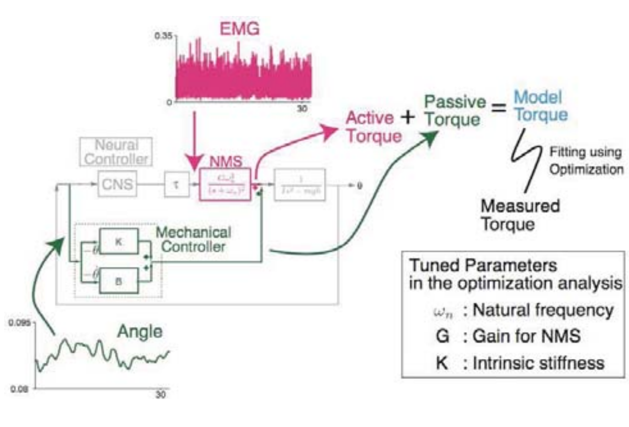

Figure 1: Scheme of the decomposition method. EMG represents the input to the neuromuscular torque generation process (NMS), which is a critically damped second order filter. The mechanical controller consists of stiffness (K) and viscosity (B), whereas the viscosity is ignorable. The natural frequency of the NMS and stiffness were identified.

DIFFERENCES BETWEEN GENDERS ON MASTICATORY MUSCULATURE ACTIVITY (EMG) OF INDIGENOUS AND WHITE BRAZILIAN PEOPLE

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AIM: Modern habits and stress may cause the collapse of stomatognathic system muscles, which generates contraction patterns different from those considered natural for humans. It is known that women are differently affected than men when they have problems, in this way, the study of primitive populations and comparing men and women subjects to civilized individuals may contribute to determining an initial pattern of muscle contraction of individuals who have not been exposed to stress factors and have healthy and natural eating and life habits.
METHODS: This study had the aim to compare the electromyographic activity of the right temporal (RT), left temporal (LT), right masseter (RM) and left masseter (LM) muscles during chewing and while maintaining postural movements (protrusion, left laterality, right laterality), between 13 indigenous men and 13 indigenous women from the Xingu village, and between 13 civilized men and 13 civilized women with ages ranging between 15 and 30 years. A twelve-channel Myosystem Br-1 electromyographer was used, and the data was analyzed using SPSS software (Chicago).
RESULTS: During maintaining rest and postural movements weren't noted statistical significance but there was the same muscles contraction pattern. Civilized women showed greater right masseter activity than indigenous women and men and civilized men during chewing grapes raisins (means - civilized women = 0.65 ± 0.09, civilized men = 0.58 ± 0.08, indigenous women = 0.45 ± 0.09 and indigenous men = 0.34 ± 0.06) and during peanut chewing in left masseter civilized men revealed grater values (means - civilized women = 0.77 ± 0.09, civilized men = 0.81 ± 0.14, indigenous women = 0.56 ± 0.09 and indigenous men = 0.47 ± 0.06) $p \leq 0.05$.
CONCLUSIONS: The data allow us to conclude that the noxious effects of modern civilization had a stronger influence on the female population, causing stress and an exaggerated recruitment of muscle fibers to perform a dynamic activity.
ACKNOWLEDGEMENTS: Financial support from FAPESP (04/11748-7 and 05/58570-0)

APPLICATION OF TIME-FREQUENCY SURFACE ELECTROMYOGRAPHIC PROCEDURES FOR THE CLASSIFICATION OF IMPAIRED MUSCLE FUNCTION IN MUSCULOSKELETAL PAIN CONDITIONS

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AIMS: This pilot study tested whether time-frequency EMG measures allow one to classify impaired back muscle function in chronic low back pain (cLBP) as different from pain free healthy subjects.
METHODS: Experiments were performed at the NeuoMuscular Research Center, Boston, USA. A total of 8 healthy subjects and 8 cLBP patients cyclically lifted and lowered a box for 4 minutes (pace: 12 lifts/minute. The box-load was 13 kg in subjects and 8.5 kg in patients. EMG signals were recorded from 12 muscle sites from trunk and limb muscles. After identification of the lifting and lowering portions of the lifting trials (cycle by cycle), time-frequency analysis methods were applied to compute the Instantaneous Median Frequency (IMDF) for the respective EMG portions of each cycle. Linear regression analysis served to calculated the EMG onsets and changes during the exercise (“fatigue slope”).
RESULTS: Patients' mean Roland Morris ratings (mean age: 39.5±12 years) were 10.3±7. At the onset of lifting, median pain ratings on an 11 points visual analogue scale were 2.0 (0.25; 3.75). At the end of lifting pain was rated 6.0 (5.25; 8.8). Full EMG data analysis was available from 6 patients and 6 controls. IMDF onset values recorded from the L5 and Th10 recording sites revealed lower values in patients than in controls for the lifting portion of the task cycles. Such difference was not observed for the lowering portion of the task. The fatigue slopes calculated for the concentric portion revealed no relevant differences between patients and healthy subjects at the gluteal and paravertebral back muscle recording sites, although patients lifted 35% less weight. Fatigue slopes recorded from the L5 electrode sites, however, differed between healthy controls and low back pain patients.
CONCLUSION: The IMDF technique has a good potential for augmenting current functional capacity evaluation procedures for patients with musculoskeletal conditions like chronic LBP and may provide a future diagnostic tool for classifying impaired muscle function in these patients.

MODELING TRANSCRANIAL MAGNETIC STIMULATION AND TRANSCRANIAL DIRECT CURRENT STIMULATION

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AIM: Transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) are techniques that can induce changes in cortical excitability. Because these techniques are easy to apply and non-invasive, it has been suggested to use them in neuroscience studies and in clinical applications. To optimize the effects of transcranial stimulation, a clear understanding of the underlying mechanisms is desirable. In order to achieve this understanding, a mathematical volume conductor model of the current induced in the human head by transcranial stimulation has to be developed.
METHODS: In this study a forward bioelectric problem is mathematically solved to obtain the induced electric potentials and current density distribution for both tDCS and TMS. A realistic head model with finite elements has been constructed for the tDCS technique, based on geometry and conductivity obtained from structural MRI and DTI measurements (Figure 1A). For the TMS technique the realistic head model is still under construction. For both the tDCS and the TMS situation, the current source has to be defined and implemented in the model. To solve the bioelectric problem for the realistic, inhomogeneous and anisotropic head model, the finite element method (FEM) has been used. The potential distribution computed by the model was compared to the measured EEG potential distribution to validate the computer-based model.
RESULTS: Preliminary results for the tDCS model and EEG measurements during tDCS, show that this computer-based model realistically describes the induced current distribution and electric potentials on the human head (Figure 1B & 1C). There are no results for the TMS model at the present time, but results are expected prior to the congress.
CONCLUSION: The preliminary results show that solving the bioelectric problem for tDCS with FEM over a realistic head model, based on MRI and DTI, is a promising method. Based on these results an even more realistic head model for tDCS and TMS will be constructed.

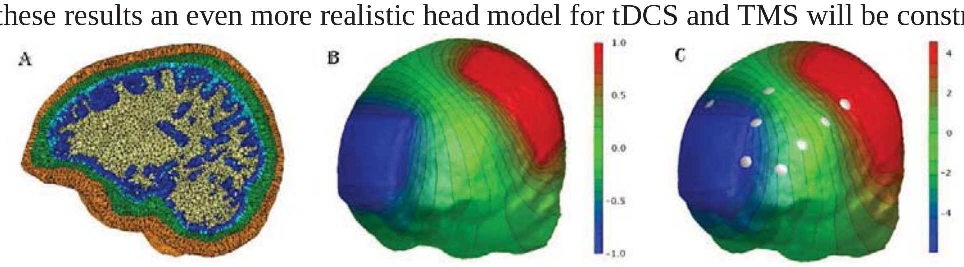

Figure 1: (A) Saggital cross-section of the head model. The different colors refer to different tissue types. (B) The computed potential (V) distribution on the scalp during tDCS (anisotropic skull). (C) The measured potentials (mV) interpolated from recorded values at EEG electrodes (at the marked positions).

EMG-BASED MUSCLE FORCE ESTIMATION: PCA-PROCESSED MULTI-CHANNEL EMG OVER THE ENTIRE MUSCLE SURFACE OF TRICEPS SURAE

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AIM: Given the potential heterogeneity of muscle structure and activation [1] and due to phase cancellation [2] one pair of bipolar electrodes over the entire muscle cannot accurately represent muscle activity. It was shown that EMG-based muscle force estimation can be improved by using multiple EMG electrodes [3]. In addition, using an unbiased (irrespective of muscle architecture) extraction method (principal component analysis, PCA), further improved EMG-based estimation of muscle force [4]. In this study, we explore the coverage of an entire muscle group and the use of PCA on the quality of EMG-based muscle force estimation.
METHODS: Nine healthy subjects performed isometric (trapezoidal shaped with isotonic phase) plantar flexions with the right extended leg in a neutral ankle position. About 120 electrodes were homogenously distributed over the entire triceps surae of each subject. We measured monopolar EMG with respect to the patella and plantar flexion moments. EMG amplitude was estimated from the monopolar signals (MON), and from the signals after removal of common information using PCA. The EMG amplitude was compared to the force pattern using correlation coefficients (r). ANOVA (repeated measures) was used with 5% significance.
RESULTS: The first PCA time-series explained about 50% of the signal power, which indicates a substantial heterogeneity in MON. High correlations were found over the entire trapezoidal pattern for MON (r=0.98±0.01) and PCA (r=0.99±0.01). In the "isotonic" plateau phase, PCA showed a 26% improvement (p=0.02) over MON (r=0.80±0.09 vs. r=0.59±0.19).
CONCLUSION: As also shown in a previous study on arm extensor muscles [3], MON EMGs do not allow a precise estimation of muscle force. When covering a large part of the muscle with multiple electrodes an improvement in EMG-based muscle force estimation can be achieved [3] when PCA processing is applied. In this study the entire muscle was covered with electrodes and high correlations were realized between PCA-processed EMG and muscle force, de . Thus, mallows quite accurate estimation of even the fine fluctuations of force during an "isotonic" contraction.

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PAIN RELATED SYMPATHETIC CHANGES IN MUSCLE FUNCTION

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Pain is a major pathway for the activation of the sympathetic nervous system (SNS) as it has been well documented in experimental and clinical conditions. Nociceptive stimuli are also commonly employed for experimentally activating the SNS in both animal and humans. Pain-related sympathetic activation is consistent with the “fight or flight” response, the arousal response aimed at protecting the organism through a reaction against a potentially dangerous or threatening stimulus, based on a powerful motor activation.

In addition to central changes that a state of arousal can operate on the motor circuitry, the motor function can be affected by several actions the sympathetic nervous system exerts at the muscle level.

First, SNS exerts a powerful control over muscle blood flow, i.e., over the fuel for muscle contraction. Secondly, by way of adrenergic receptors located on the sarcolemma targeted by circulating catecholamines, the SNS modulates several intracellular functions in skeletal muscle fibers that are relevant for muscle performance, like contractility and ionic exchange across the sarcolemma. Thirdly, a modulatory action on proprioceptive information from muscles spindles is also potentially capable to influence the motor output.

Most of these actions have a functional meaning in supporting the high motor demand of the fight-or-flight response. On the other hand, due to social constraints, sympathetic activation may often occur unrelated to intense motor activity. In this condition, the SNS-induced changes in the muscle effector may not be appropriate for the conduction of normal movements and motor tasks. They require the voluntary motor command to be adjusted accordingly, leading to the adoption of sub-optimal motor strategies. Some of these actions were hypothesized to cause derangements in skeletal muscles and link sympathetic hyperactivity to the development of chronic muscle pain syndromes, based on the fact that developing muscle pain may reinforce sympathetic activity and give rise to positive feedback loops (Passatore and Roatta 2006).

However a number of issues should be carefully considered. Sympathetic activation is not a stereotyped event but may occur in a wide range of patterns which differently affect different tissues and organs, depending on the type of stimulus. The individual psychological/affective interpretation of the stimulus (e.g., a painful stimulus) may greatly affect the actual sympathetic response. Responses to acute stimuli in healthy organisms are not necessarily predictive of the responses occurring under chronic exposure to the stimulus or in pathological conditions.

Passatore M and Roatta S. Influence of sympathetic nervous system on sensorimotor function: whiplash associated disorders (WAD) as a model. Eur J Appl Physiol 98:423-49, 2006

TRANSVERSE VS LONGITUDINAL TRIPOLAR CONFIGURATION FOR SELECTIVE STIMULATION WITH MULTIPOLAR CUFF ELECTRODES

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AIM: To compare the commonly used longitudinal tripolar nerve cuff configuration (LTC) with the transverse tripolar configuration (TTC) in terms of selectivity with respect to activation of (groups of) fascicles in peripheral nerves.
METHODS: Acute experiments were performed in five anaesthetized rabbits. Stimulation was delivered in either the LTC or the TTC through a multipolar cuff electrode implanted on the sciatic nerve. This electrode had an inner diameter of 2.4 mm and contained four 0.5x0.5 mm contacts at 90˚ intervals around the inner circumference at the middle of the cuff and a 1 mm wide ring contact at each end of the cuff, 7.5 mm from the middle. Evoked nerve signals were recorded from each of the three branches of this nerve (tibial (T), common peroneal (CP), and caudal cutaneous (CC)) to evaluate the stimulation selectivity. Measured peak-peak responses (v_{pp}) were normalized (Nv_{pp}) to the largest response measured on the same nerve during the experiment. A selectivity index (SI) was calculated as the Nv_{pp} of the best recruited nerve branch divided by the sum of the Nv_{pp} of all three branches. A nerve branch was regarded as selectively activated in a functionally relevant way if both the criteria $SI > 0.7$ and $Nv_{pp} > 0.7$ were satisfied. The stimulation current required to produce 10% activation of the nerve was calculated from a sigmoid fit of the recruitment curve.
RESULTS: For the LTC functionally relevant selective activation was achieved for CP and CC in rabbit 1, CP in rabbit 2, CP and CC in rabbit 4, and CP in rabbit 5, i.e. in total in 6/15 nerve branches. For the TTC functionally relevant selective activation was achieved for T, CP, and CC in rabbit 1 and 2 and for CP and CC in rabbit 3, 4, and 5, i.e. in total in 12/15 nerve branches. The best achieved functionally selective SI, Nv_{pp}, and threshold stimulation intensity were 0.83±0.09 (mean±std.), 0.83±0.07, and 82±36 μA, respectively, for the LTC and 0.95±0.08, 0.90±0.07, and 0.40±0.31 mA, respectively, for the TTC. The difference between the configurations was statistically significant for SI (p=0.009) and for the threshold current (p=0.009), but not for Nv_{pp} (p=0.06) (Mann-Whitney-U Test).
CONCLUSION: The current study obtained an excellent performance of the TTC as compared with the literature, which is probably related to a relatively high contact spacing, allowing a large proportion of the current into the nerve. The TTC can provide a useful tool to optimize spatial selectivity of multipolar cuffs.
ACKNOWLEDGEMENT: The authors thank the staff at Aalborg Hospital for their assistance. This study was supported by the Danish National Advanced Technology Foundation.

THE REQUIRED NUMBER OF EPOCHS FOR REPRESENTING BRAIN STATES FROM SPONTANEOUS EEG

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AIM: One of the commonly used methods to investigate different states of the brain, using EEG, is to analyze spectral power values spatially distributed over the scalp. The continuously recorded data of a certain situation is therefore cut into shorter time periods followed by calculations of power spectra for each so called epoch. By averaging these spectra, the characteristic power spectrum for each electrode position is obtained. Due to the stochastic nature of EEG signals, the number of artifact-free epochs determines the reliability of the representation of cortical activity. Especially in sports medical investigations, particularly motion artifacts lead to a considerable loss of epochs. The aim of this paper is to investigate how many EEG-data epochs are necessary to reliably describe the characteristics of a state of brain and whether there are dependencies on the task, channel or frequency band.
METHODS: For this investigation EEG data of ten male subjects in two different conditions (resting with eyes closed - EC, knee angle reproduction task - AR) was used. In current studies we are focused on analyzing the fronto-parietal network represented by electrode positions F3, FZ, F4 in the theta (4.75-6.75Hz) band and P3, PZ, P4 in the alpha2 (9.75-12.5Hz) band according to the standard 10-20-System. Originally, all data consist of a minimum of 20 artifact-free 2 s epochs. To compare the effect of averaging different numbers of epochs, 5, 10 and 15 epochs were randomly picked out of the 20, for each subject and condition. Spectral power values were compared by calculating the Pearsons product-moment correlation coefficients between data sets with 5, 10, 15 epochs respectively and 20 epochs (5-20eps, 10-20eps, 15-20eps) and their coefficient of variation.
RESULTS: As shown in table 1, correlation coefficients are well above r=.8 (p<.02) in all data sets and tasks. Additionally, coefficients of variation for data sets 10-20eps and 15-20eps do not reach values above 9.3% but exceed this threshold in data set 5-20eps, except for the AR task.
CONCLUSION: From these findings we suggest that at least 10 epochs must be taken into account to obtain reliable representations from spontaneous EEG. However, results also indicate that in certain tasks and frequency bands even 5 epochs are sufficient for investigations of the fronto parietal network.

		EC			**AR**		
		5-20eps	**10-20eps**	**15-20eps**	**5-20eps**	**10-20eps**	**15-20eps**
Theta frontal	r	>.84	>.87	>.87	>.93	>.93	>.96
	cv [%]	<16.1	<8.6	<8.1	<14.3	<9.3	<8.6
Alpha2 parietal	r	>.99	>.99	>.99	>.94	>.98	>.96
	cv [%]	<15.5	<8.7	<6.2	<9.8	<9.0	<8.3

Table 1: comparison of correlation coefficients (r) and coeffiecients of variation (cv) in EC and AR conditions of data sets

EMG- AND TORQUE-FEEDBACK CONTROL DURING SUBMAXIMAL POSTECCENTRIC QUADRICEPS FEMORIS CONTRACTIONS AT 30% MVC

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AIM: Stretch of activated muscles leads to posteccentric force enhancement (FE) compared to purely isometric contractions at the same muscle length. In vivo, this is also proofed to be a property of small and medium sized muscles at submaximal activation. The purpose of this study was to examine if this phenomenon also exists in submaximal voluntary activated large human muscles (quadriceps femoris, QF) controlled by EMG- and torque-feedback.
METHODS: Real-time visual feedback of EMG signals (vastus lateralis (VL), RMS 2s), as well as torque signals was given for standardized control of submaximal pure isometric (100° knee flexion angle) and isometric-eccentric-isometric muscle contractions (80-100°, 60°s^{-1}). The level of activation and torque was set to 30% of individual maximal voluntary contraction (MVC) and displayed as a reference line. Torque and EMG data of VL, r. femoris (RF) and v. medialis (VM) was collected 3 and 5s after stretch (RMS 2s). ANOVA (α=0.05) served for analysis of parameters of 15 subjects concerning contraction conditions and time.
RESULTS: EMG controlled stretch-contractions showed significantly enhanced posteccentric torque (72.7±15.8Nm, 69.1±15.2Nm) compared to purely isometric contractions (64.6±14.1Nm, 64.1±14.2Nm) at 3 and 5s after stretch. Additionally, there was a significant decrease in torque of stretch-contractions over time. In contrast, torque control did not lead to decreased muscle activation of VL, RF and VM in stretch-contractions.
CONCLUSION: It is possible to standardize submaximal activation of VL within 3% standard deviation (Fig. 1a, b) and the results show that posteccentric FE is present in voluntary activated QF at 30% MVC. Although torque decreased over time, FE is proofed to appear in everyday life efforts and therefore needs further implementation in the common understanding of muscle function. Nevertheless, this seems not to be valid in reverse, when torque is controlled and FE would be defined as decreased activation (in terms of more efficient muscle control). The question whether this is a property of human QF or maybe a result of the neurophysiological abilities to control the activation of such a large muscle by visual feedback needs further investigation in submaximal levels of MVC.
ACKNOWLEDGEMENT: This study is supported by the German Research Foundation (DFG, www.dfg.de). Thanks to Lasse Jagschies for his help in preparing the analysis tools.

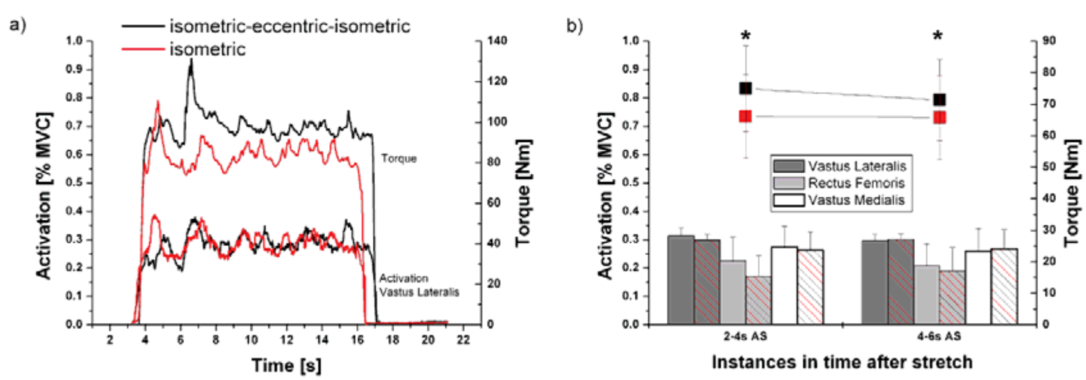

Figure 1: Exemplar (a, n=1) and means (b, n=15) of torque and activation (RMS 500) of submaximal isometric (red) and isometric-eccentric-isometric (black) contractions.

MULTICHANNEL SURFACE EMG TO DETERMINE THE MUSCLE FATIGUE AT OVERHEAD AND OVERSHOULDER WORK OF COMPLETE SHIFTS

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AIM: Assembly workers are complaining about neck or shoulder muscle discomfort caused by overhead or overshoulder work. The complaints can be categorized as muscle fatigue, muscle pain, movement limitations or impairments (i.e. impingement syndrome). The aim of this pilot study was to test the practicability of complete-shift EMG measurements representing a necessary basis for determining muscle fatigue under real working conditions. Besides, a proper work encoding procedure should be tested.
METHODS: Before measuring at an assembly line of a German car manufacturer, video recordings of the work tasks from two employees have been made to identify typical working postures.
The measurement includes a description of work tasks and the working environment. To enable identification of muscle fatigue, a measurement of the muscular activity was performed via bipolar surface EMGs. The activity was derived of the m. trapezius (descending part; left and right) and the m. deltoideus (anterior, middle and posterior part; left and right). The recordings were performed over two complete shifts from two different workers; each shift lasted approx. 7 hours. To synchronize work content with the EMG data, the different tasks were encoded with up to 7 different code categories, depending on the work task.
RESULTS: First measurements on two workers have been completed. The EMG data recordings have a duration of about 14 hours. Four different work tasks, including two with overhead or overshoulder elements, have been studied. The tasks with overhead or overshoulder elements are “laying a wiring loom in the tailgate” (duration approx. 5 minutes per task) and “mounting the hook for the engine bonnet lock” (duration approx. 45 seconds per task). The remaining two tasks are “mounting a windscreen wiper motor and applying mounting brackets” (duration approx. 45 seconds per task) and “putting a protection cover on the wiring looms” (a few seconds per task; not encoded in detail). Each of these tasks is repeated a few times until the working person changes to one of the other tasks. The time between cycles of tasks is depending on the size of the work team, personal preferences and training degree. In total, cycle time ranges between 30 and 90 minutes.
CONCLUSION: It was possible to measure EMGs during complete shifts without disturbing the operational procedure, the encoding regiment is working well so far, but further studies are needed to be able to get reliable results on muscle fatigue.

TECHNICAL BACKGROUND, PRACTICAL GUIDELINES AND INTERPRETATION OF EMG SIGNALS

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AIM: (1) to provide technical background information, (2) practical guidelines for using different systems of surface electromyography (EMG) within the analyses of human movement in sports and clinics and (3) possibilities and limitations of the interpretation of the EMG signals.
METHODS: (1) The technical background of current EMG systems is given, including fundamental information about

- recording frequencies and AD-board quality and requirements,
- benefits , methods and requirements of signal pre-amplification and
- advantages and disadvantages of wireless vs. wired EMG systems.

(2) Practical help and advice is given for the application of EMG systems in movement analysis including:

- skin preparation, positioning and fixation of surface electrodes,
- the minimization of artifacts or signal losses and
- considerations of additional parameters to be extracted from long term EMG recordings.

(3) The possibilities and limitations in interpreting surface EMG depend on research question, type of analyzed movement and technical restrictions. Special emphasis is given to the time and frequency domain of dynamic EMG signals when recording sport movements.
RESULTS: The presented technical background of EMG measurements should help to better understand the possibilities and limitations of EMG applications and interpretation within the biomechanical analysis of human movements. The quality of a recorded EMG signal is depending on a number of physiological factors e.g. tissue composition, impedance and temperature and technical factors e.g. inter-electrode distance, signal to noise ratio and amplification linearity and signal transmission methods. Positioning and fixation of the electrodes cables and pre-amplifiers should provide minimal movement related to the muscle. Adequate recording frequency, amplification and filtering differ for static and dynamic conditions and have to be chosen according to the movement characteristics and research question. In addition in high dynamic movements or long term recordings, evaluating additional parameters like skin impedance, temperature and kinematic movement data is necessary to improve interpretation of the EMG data. Consequently, in most cases EMG is integrated into an instrumented motion capture system. Wireless EMG systems provide greater mobility than wired systems, but can have drawbacks in terms of data security and synchronization with other data sources depending on the transmission technology.
CONCLUSION: The knowledge of the technical background of EMG and the correct application of the system and its settings significantly improves the quality of the recorded EMG signals. In addition, the use of an adequate data processing in the time, amplitude and frequency domain of the EMG signals is necessary to obtain meaningful interpretation. Therefore understanding the fundamentals of EMG helps to use this method as a tool to improve understanding of human movement.

MODIFICATIONS OF UPPER LIMB MUSCLE SYNERGIES IN POST-STROKE PATIENTS DURING REHABILITATION BASED ON FUNCTIONAL ELECTRICAL STIMULATION

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AIM: Previous experiments have suggested that the CNS may coordinate muscle activations through a linear combination of muscle synergies. Neurological diseases influence motor recruitment and, consequently, modify muscle synergies. Our purpose was to understand the modifications induced by Functional Electrical Stimulation (FES) in post stroke patients during upper limb rehabilitation. To this aim we compared muscle synergies pre and post intervention.

METHODS: Five chronic stroke participants undertook nine tracking tasks in a planar robot in which trajectory (orientation and length), duration, speed and resistance were varied. Error in target tracking was corrected by electrical stimulation of the triceps muscle. Timing and level of stimulation was adjusted using iterative learning control algorithms. EMG signals were collected at 1500 Hz from 7 upper arm and shoulder muscles (Biceps BIC; Anterior Deltoid DEL_A; Pectoralis major PEC_M; Trapezius, upper TRAP_UPP, medial TRAP_MED, lower TRAP_LOW; Triceps TRI), both before and after 18 treatment sessions. The same EMG data was collected under the same conditions with 8 neurologically intact participants on a single occasion. Raw data were rectified, low-pass-filtered (Butterworth, 4th ord., 20 Hz) and normalized to their maximal values. Muscle synergies were extracted using the Non-Negative Matrix Factorization algorithm. Differences in weight coefficients and timing patterns between the groups have been respectively evaluated by means of their scalar product and their correlation coefficients.

RESULTS: Preliminary results showed statistically significant differences between muscle synergies extracted from impaired and healthy subjects. However, despite of improved motor performance following the intervention, there were no statistically significant changes in muscle synergies.

CONCLUSION: The present study shows that muscle synergies in chronic stroke patients differ from normal but are not modified by this intervention. Concomitant improvement in motor performance in the absence of significant normalisation of muscle synergies implies reinforcement of residual motor strategies acquired after stroke. Improvement in functional may be through compensation rather than true recovery and potentially demand a greater energy cost.

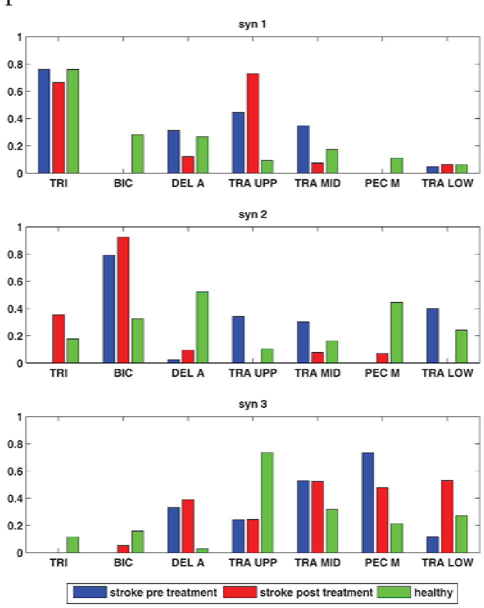

Figure: Representative muscle synergies for a stroke and a healthy subject.

FORCE ENHANCEMENT DURING AND AFTER MULTIJOINT LEG EXTENSION

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AIM: Force enhancement is a well accepted property of skeletal muscle but knowledge about its relevance in daily living remains limited. The purpose of this study was to determine whether there is force enhancement during maximal voluntary multi-joint leg extension.
METHODS: Human multi-joint leg extension was studied (n = 22) on a motor driven leg press dynamometer where external reaction forces under the feet as well as EMG-activity of 8 lower extremity muscles were measured. In addition, torque in the ankle and knee joints was calculated using inverse dynamics. The steady-state isometric force, joint torques and muscle activation after active stretch (20° stretch amplitude at 60°/s) were compared with the corresponding values obtained during isometric reference contractions.
RESULTS: There was consistent force enhancement (FE) during and following stretch for both, forces and joint torques. Potentiation during stretch reached values between 26 and 30%, while a significant force enhancement of 10.5 - 12.3% and 4.3 - 7.4% remained 0.5-1 second and 2.5-3 seconds after stretch, respectively (Fig. 1). During stretch, EMG signals of m. gastrocnemius medialis and lateralis were significantly increased, while following stretch all analyzed muscles showed the same activity as during the reference contractions. However, FE during stretch was influenced by joint kinematics and technique variations such as shifting of COP under the feet in conjunction with changing the line of action of the force.
CONCLUSION: We conclude from these results that force enhancement exists in everyday movements like multi-joint leg extension. Thus it seems reasonable to account for FE in models of human movement, in motor control studies and in studies of human performance. In order to incorporate the characteristics of FE into biomechanical models, further research is needed since everyday movements are performed with submaximal muscle activations and a variety of ROMs. The amount and duration of FE depending on different submaximal activation levels and stretch amplitudes is therefore of major interest for a more complete description of the force enhancement phenomenon. However, the question arises how to standardise submaximal voluntary muscle activation for a multi-joint contraction.

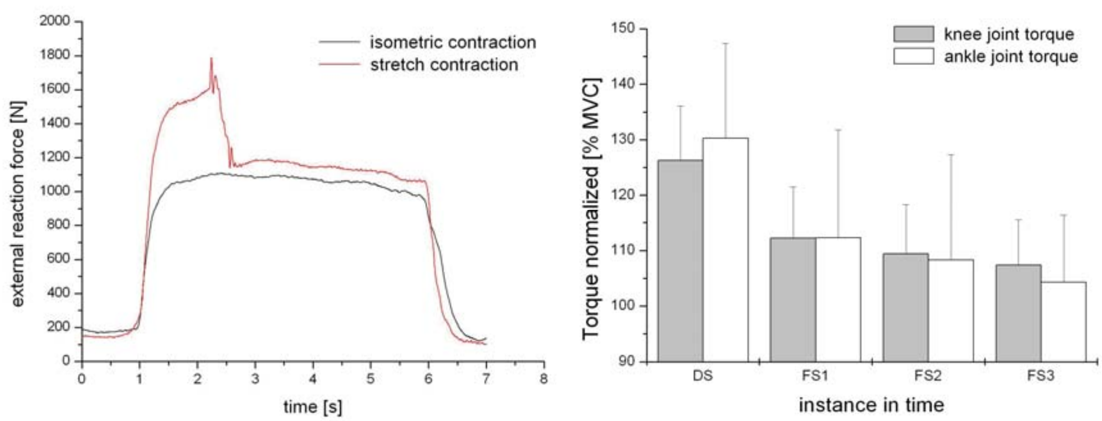

Figure 1: The left graph illustrates exemplar smoothed force data for isometric and stretch contractions. The right graph shows the amount of FE during (DS) and following (FS) stretch. Potentiation showed significance ($p < 0.05$) for both joints and all instances in time.

MECHANISMS FOR INTEGRATING THE "Wii-GAME" AND ROBOT FOR THE TRAINING OF UPPER EXTREMITIES IN HEMIPLEGICS

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AIM: The task of the research was to develop the mechanism that can be used for integration of the challenging and motivating game, in this case Nintendo Wii, with the robot that is designed for the training of the upper extremities of hemiplegic patients. The robot is envisioned as the trainer by providing the appropriate force to a patient while playing the game (learning from the robot how to move). The force exerted to the patient follows the force estimated while an expert plays the same game (learning from an expert).
METHODS: We introduce the Nintendo Wii game as a very motivating feedback to be the part of a robot based trainer. Nintendo Wii allows two types of games: competitive, in which the player has a competitor (other player or the Wii) with whom he/she directly interact and its actions are the results of such interaction (e.g., table tennis); and noncompetitive, in which the player needs to find a strategy to maximize performance. The task may be of targeting type, or may involve the control of an (unfamiliar) tool or device (e.g., bowling, flying a plane). We are developing mechanical interfaces which allow implementation of Wiimote (control interface) when the user is disabled and has limited ability to move the hand.
RESULTS: We developed two types of mechanical adaptors for transforming simple 2D movements into the desired sufficiently accelerated 3D motions of the Nintendo Wii controller (Wiimote); thereby, several games from the Wii repertoire for the exercise can be played. The system developed, provide sufficient adaptability to allow various movement (from very slow to healthy-like, from low joints range to healthy-like); hence patients with different levels of disability can participate.
CONCLUSION:The handle of the robot can be integrated with the system alike Brachio di Ferro, Genova, Italy This allows direct implementation of haptic control which has already been proven to be effective in the training of hemiplegic patients.

Figure 1: 2D pantograph with adaptable lengths of arms, remotely positioned switches A and B, and the Wiimote fixed to one arm of the pantograph (left panel), the pantograph in use for bowling game (middle panel), and Brachio di Ferro robot that is envisioned to be connected with the pantograph (e.g., the same handle) and used as the robot trainer (right panel).

ACKNOWLEDGEMENT: This work is part of the research HUMOUR, FP7-ICT-231724. The work was partly supported by the Ministry of Science and Technology of Serbia, Belgrade.

IDENTIFICATION OF INCORRECT DECISIONS OF BRAIN-COMPUTER INTERFACES FROM CORTICAL POTENTIALS

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AIM: A Brain-Computer Interface (BCI) is a system that allows communication between the brain and a computer or other external devices, without the use of nerves or muscles. The inputs of the system are usually EEG signals. The output is a decision of action among a set of possible ones (e.g., a command to a prosthesis). The core of a BCI is thus a classification algorithm, and a training session is used to build the decision rules that allow the decoding of the user's intention. In order to adapt the decision system to the changes in user's conditions, it is necessary to identify online the set of trials corresponding to correct decisions. The aim of this work is to estimate online if the decision provided by a BCI system is correct or wrong, by classifying cortical potentials recorded after the BCI response is displayed to the subject, and supposed to contain pertinent information about the decision.

METHODS: Two approaches have been used and compared for evaluating the accuracy of the BCI decision from cortical potentials:

The first approach corresponds to a problem of supervised bi-class (correct/wrong) classification: the cortical potentials are mapped into the space of signal descriptors (subband power spectrum, discrete wavelet transform coefficients, or signal samples) and classified using a robust classifier (support vector machine, SVM) learnt on a training set composed of labeled signals (correct or wrong). The second approach corresponds to a detection system: for each potential, the detection index is defined as the crosscorrelation between the signal and an averaged potential of the class correct. This index is compared to a threshold to decide if the signal belongs or not to the class correct. Averaged potential and threshold are learnt on a training set. Two thresholds (Thres1, Thres2) are used, calculated in order to obtain at least 80% (resp. 90%) of well classified in the class wrong (i.e., 20%, resp. 10%, of the wrong BCI decisions are estimated as correct).

The two methods were evaluated on a test set using the leave-one-out procedure on experimental signals recorded from 11 subjects (corresponding on average to 120 trials in the class correct and 40 trials in the class wrong for each subject).

RESULTS: Table 1 gives, for each class, the mean percentages of well classified potentials obtained with the classification approach (Clas.) for three types of features, and using the detection approach (Det.) with the thresholds Thres1, Thres2.

Table 1 :

Method	Clas.Spectrum		Clas.DWT		Clas.Signal		Det.Thres1		Det.Thres2	
Class	Correct	Wrong	Correct	Wrong	Correct	Wrong	Correct	Wrong	Correct	Wrong
% well class.	87	48	80	65	78	67	65	84	59	92

CONCLUSION: When using temporal features for classification, the two approaches proposed had similar performance with accuracy ~74%. Therefore, cortical potentials contain pertinent information for discriminating correct and wrong decisions made by a BCI system. The detection method allows the selection of the false positive rate, that is crucial when it is necessary to include in the decision system only the trials corresponding to correct BCI decisions.

VITAMIN AND MINERAL SUPPLEMENTATION EFFECT ON MUSCULAR ACTIVITY AND CYCLING EFFICIENCY IN MASTER ATHLETES

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AIM: The influence of vitamin and mineral complex supplementation on muscular activity and cycling efficiency was examined during a heavy cycling trial in master athletes.
METHOD: Two groups of 8 masters athletes, regularly trained in endurance, were randomly assigned in a double-blind process to one of two treatment groups: antioxidant supplementation (As group) or placebo (Pl group) for 21 days. After the 21 days of supplementation each subject had to perform two 10 min cycling sessions on cycloergometer at the same heavy constant intensity. During each cycling bout, cycling efficiency was recorded. The second session was preceded by a fatiguing strength exercise on a leg press. Maximal voluntary contraction (MVC) of knee extensors was assessed before and after fatigue. Electromyographic (EMG) activity of thigh muscles was recorded with surface electrodes.
RESULTS: The knee extensors MVC after fatigue was significantly reduced in similar proportions in both groups (As. -10.9%; Pl. -11.3%, $p<0.05$), associated with a significant reduction in EMG frequency parameters in both groups, with lower decrease in As group. Muscular activity and efficiency during the cycling bouts were affected by the treatment. Cycling efficiency was significantly decreased and VO_2 slow component (VO_2SC) was higher after the fatiguing exercise in both groups. Furthermore, decrease in cycling efficiency was associated with an increase of VL activity (figure 1). However, these changes were significantly lower for As group.
CONCLUSION: Results of the present study report an overall positive effect of the vitamin and mineral complex supplementation on exercise tolerance after fatigue in master athletes.
ACKNOWLEDGMENT: This research received financial support from the NHS laboratory located in Rungis (Val-de-Marne, France).

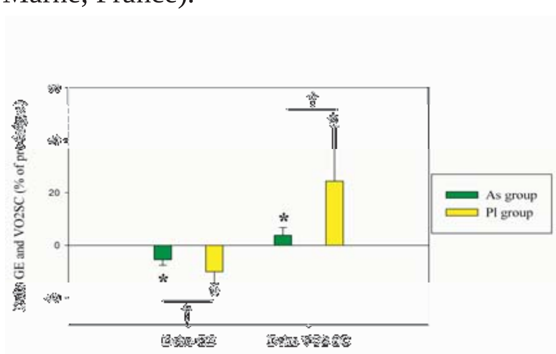

Figure 1: Changes in gross efficiency (GE) and oxygen uptake slow component (VO_2SC) during cycling between pre and post-fatigue conditions, in antioxidant (As) and placebo (Pl) supplemented groups. Values are means ± SD. *, significantly different from pre-fatigue; †, significant difference between As and Pl groups.

S-EMG CONDUCTION VELOCITY ESTIMATION USING IMAGE PROCESSING TECHNIQUES

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AIM: Multi-channel surface electromyography (S-EMG) allows the extraction of anatomical and physiological information of motor units (MUs). The information obtained with this technique can be presented as an image, enabling the use of image processing techniques to assess the features of the signal. In this work, we represented S-EMG signals as images in order to estimate the average motor unit conduction velocity (CV).
METHODS: A time window from 12-channel S-EMG signals was selected to interpolate samples and channels, obtaining an image similar to Figure 1. Then, Hermite filter was used to estimate the instants and channels where MU action potentials (MUAPs) are traveling. The image is then processed to obtain and label all the conduction lines and identify the minimum and maximum points of each line that represents MUAP conduction. From these data, it is possible to find the mean conduction velocity of the window.
RESULTS: The tool was tested in synthetic signals, with known CV, and real signals, achieving better estimates compared to a traditional method (maximum likelihood). Table 1 shows the results from both traditional and image processing method.
CONCLUSION: Image processing techniques can estimate CV from synthetic and real multi-channel S-EMG signals with good performance for all the cases showed in Table 1. The technique was able to estimate CV when the signal presents high level of noise and even if the innervation zone is on the image.
ACKNOWLEDGEMENT: We would like to thank Prof. R Merletti and the researchers at LISiN (Politecnico di Torino, Italy, www.lisin.polito.it) where this research started, and GPDS (UnB, Brazil, www.ene.unb.br/gpds) for all the help and support.

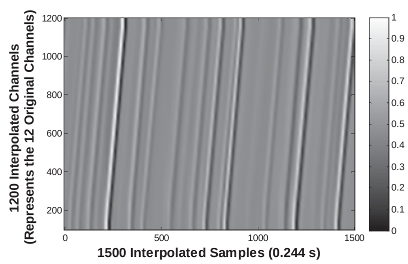

Figure 1: Image based in a Multi-Channel S-EMG. The lines represent different propagating MUAPs.

Table 1: Comparison between Image Processing and Maximal Likelihood for CV estimation

Signal	*CV – Image Processing (m/s)*	*CV – Maximal Likelihood (m/s)*	*Real CV (m/s)*
Synthetic	4.176	4.068	4.0
Syn. With IZ	4.449	5.368	4.0
Syn. 12dB SNR	4.085	3.194	4.0
Real	4.135	5.299	~4

STANDARDIZATION OF THE ELECTROMYOGRAPHIC SIGNAL THROUGH THE MAXIMUM ISOMETRIC VOLUNTARY CONTRACTION

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AIM: To standard an electromyographic signal (EMG) is trying to reduce the differences between the records of the same subject, or different subjects to make the interpretation of the data reproducible. The standardization of the EMG signal has been described in the literature as essential for comparisons between subjects, days of measurement, or muscles are several studies and standardization of procedures EMG signal. This study aimed to analyze the data EMG before and after the standardization of data.
METHODS: For that 100 normal subjects participated in this study. It was carried out of surface electromyography of masseter and temporal muscles of both sides earlier. Two tests were performed: maximum voluntary contraction (MVC) on cotton rolls and MVC in a position of maximum intercuspation. The standardization of the EMG signal was performed by the value of the peak of the signal of the first examination.
RESULTS: The results of the calculation of the variation coefficient (VC) showed a large amount of VC data for non-standard (Table 1) and lower values of VC for the standardized data (Table 2).
CONCLUSION: It was concluded that the standardization of data through the peak of the signal during a MVC was effective in reducing the differences between records of the same subject and different subjects.

Table 1: Summary of data in R.M.S. in micro-volts. Test 1: MCV with cotton rolls; Test 2: MCV in PMI.

Exam	Muscle	Side	N Obs.	Mean	Standart Deviation	CV	Minimum	Median	Maximum
1	Masseter	Right	100	217,46	146,89	67	40	174,9	957,2
		Left	100	208,57	142,83	68	18,3	169,9	764,2
	Temporal	Right	100	174,95	94,64	54	37,8	153,35	772
		Left	100	185,86	85,53	46	66,5	169,35	544,3
2	Masseter	Right	100	204,85	136,87	66	34	181,25	892,8
		Left	100	194,15	130,63	67	26,2	163,2	704,42
	Temporal	Right	100	187,53	112,96	60	17,5	156,9	697,8
		Left	100	195,49	110,43	56	23,7	165,24	691,6

Table 2: Summary of data in R.M.S. After standardization of the data (%).

Exam	Muscle	Side	N Obs.	Mean	Standart Deviation	CV	Minimum	Median	Maximum
Standardized Data	Masseter	Right	100	102,88	49,93	48	27,1	93,3	321,6
		Left	100	103,77	49,08	47	24,2	93,55	284,9
	Temporal	Right	100	110,66	43,04	38	34,1	103,75	359,5
		Left	100	106,93	33,6	31	25,1	100,65	241,7

INSTRUMENTAL EVALUATION OF THE STOMATOGNATHIC SYSTEM: ANALYSIS OF THEIR CONTRIBUTION TO THE DIAGNOSIS AND MONITORING OF TMD PATIENTS TREATED WITH OCCLUSAL SPLINTS

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AIM: The aim of this study was to analyze and compare the activity of pairs of muscles through electromyography, during testing of dental clenching and and analyze the performance of the masticatory muscles by measuring the bite force before and after treatment with occlusal splint.
METHODS: The sample consisted of 15 subjects with temporomandibular disorders (TMD) and 15 control subjects without signs or symptoms of TMD according to the classification proposed by the protocol of the Research Diagnostic Criteria for Temporomandibular Disorders - RDC / TMD. The electromyographic examination and bite force were performed at the Laboratory of Research in Electromyography of the Stomatognathic System.
RESULTS: There was no statistically significant difference when compared bite force between TMD groups before and after treatment, but bite force values in control group was higher than the TMD before and after treatment (Table 1). There was a statistically significant difference when compared these rates between the study variables of electromyographic analysis (Table 2). The symmetry index values in the Control Group were higher than the TMD Initial Group and similar to the TMD Group after the treatment with splint. The index values of torque were higher in TMD Initial Group when compared with the Control.
CONCLUSION: The occlusal splints may be used as complementary or adjunctive in the treatment of temporomandibular disorders.

Table 1: Results of bite force analysis of groups in study. Table shows mean ± standard deviation, unit: kgf.

	Right	Left
TMD before	34,24 ± 3,57	32,41 ± 1,78
TMD after	30,71 ± 1,77	30,50 ± 2,54
Control Group	37,46 ± 2,00	40,22 ± 1,95

Table 2: Summary of study variables of electromyographic analysis. Table shows mean ± standard deviation, unit: %.

	POC temp	POC mm	Tors	POC medio	Assim
TMD before	82,11 ± 8,34	82,05 ± 10,02	12,95 ± 6,78	82,06 ± 6,98	5,46 ± 9,82
TMD after	84,67 ± 6,26	85,02 ± 6,96	11,31 ± 7,18	84,85 ± 6,33	0,43 ± 8,12
Control Group	87,66 ± 1,80	87,81 ± 1,20	8,65 ± 0,57	87,73 ± 0,99	0,14 ± 4,46

IMMEDIATE EFFECT OF THE RESILIENT SPLINT EVALUATED BY SURFACE ELECTROMYOGRAPHY IN PATIENTS WITH TMD

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AIM: This study aimed to analyze the immediate effect of resilient splints through surface electromyography test and compare the findings with the electromyographic profile of asymptomatic subjects.
METHODS: The participants were 30 subjects, 15 patients with TMD (TMD Group) and 15 healthy subjects (Control Group) classified according to Research Diagnostic Criteria (RDC/TMD) Axis I. It was made a resilient occlusal splint with coverage of all the dental elements of 2 mm thick, silicon, for each patient from TMD Group. The EMG examination was performed before and immediately after installing the splint, where 3 tests were performed: 1. Maximum Voluntary Contraction (MVC) with cotton rolls (standards test), 2. MVC in Position of Maximal Intercuspation; 3. MVC with the splint in position. The EMG signal was recorded for 5 seconds. EMG indices were calculated that assessed muscle symmetry, jaw torque and impact.
RESULTS: There was a statistically significant difference when compared these rates between the study groups. The symmetry index values in the Control Group were higher than the TMD Initial Group and similar to the TMD Group after the installation of the splint. The index values of torque were higher in TMD Initial Group when compared with the Control. Impact values were lower than normal values in TMD Initial Group and restored when the installation of the splint.
CONCLUSION: The resilient occlusal splints may be used as complementary or adjunctive in the treatment of temporomandibular disorders.

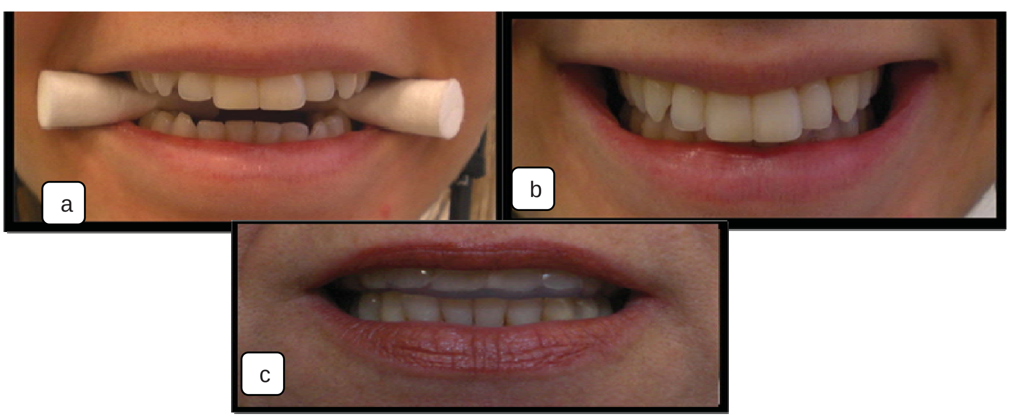

Figure 1: a. Maximum voluntary contraction (MVC) with cotton rolls of 10mm thick positioned between the second premolar and first molar on each side; b. MVC without cotton rolls in the Position of Maximal Intercuspation; c. MVC with the resilient occlusal splint in position.

POSITION CONTROL IN FIBROMYALGIA

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AIM: Impaired motor control during precision tasks has been observed in the painful muscles of several chronic pain syndromes with localized musculoskeletal pain. However, motor control in patients with global pain syndromes remains unclear. The aim of the present study was therefore to investigate the position control of upper limb segments in fibromyalgia patients (FM).

METHODS: Fifteen female FM-patients and 13 healthy age- and sex matched controls were asked to keep a constant joint angle during elbow flexion and shoulder abduction tasks. The subjects received real time visual feedback of their joint angle. They performed both tasks unloaded and while supporting initial loads (1, 2, & 3 kg). Vertical acceleration of the forearm and upper limb was measured using accelerometers. The data was analyzed by power spectrum analysis.

RESULTS: The power spectrums showed two prominent frequency bands where most of the energy was located: 2-5 Hz and 8-12 Hz. The fibromyalgia patients had a higher % of the total energy located in the low frequency band, and a lower % of total energy in the high frequency band compared with healthy controls (**P**<0.05). The results were consistent for all weight trials, and for both elbow flexion and shoulder abduction (see Figure 1 for example). The only difference between the groups in overall variance (SD) of the mean joint angle was a higher SD in the patient group in shoulder abduction supporting an initial load of 2 kg (**P**<0.05).

CONCLUSION: Fibromyalgia patients seem to have a different neuromuscular control strategy during elbow flexion and shoulder abduction position tasks compared with healthy controls.

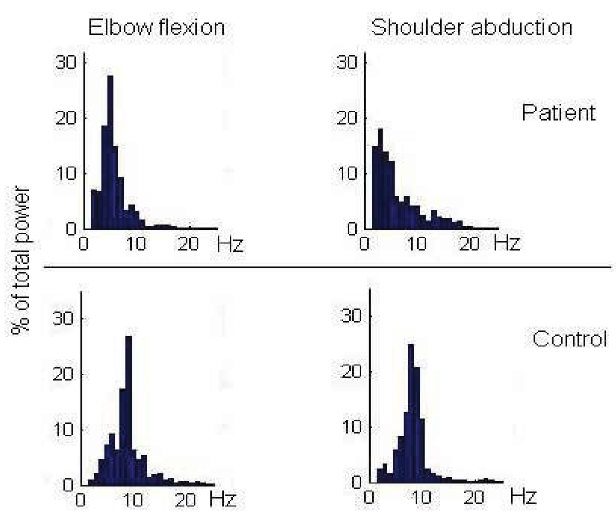

Figure 1: Example of how power of vertical acceleration is distributed over the frequency spectrum during unloaded elbow flexion and shoulder abduction for one patient (upper panel) and one control (lower panel).

A METHOD TO MONITOR THE STATUS OF FUNCTIONAL RECOVERY IN TENDINOPATHIES: A COMBINATION OF EMG AND STRENGTH MEASUREMENTS

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AIM: Lateral elbow tendinopathy or tennis elbow (TE) is one of the commonest elbow problems causing pain and thus restricting performance and function. It is commonly considered a degenerative tendinopathy of the origin of extensor carpi radialis (ECR) muscle. The aetiology is likely to be multi-factorial and the optimal treatment remains undefined. Recovery time may vary between 6 months to 2 years. A reliable method is required for monitoring and assessing the status of recovery in TE. We aimed to: (a) investigate changes in muscular strength, fatigue and activity in recovered TE (RTE); (b) assess the appropriateness of EMG and strength measurements in monitoring functional recovery in TE.
METHODS: Study included three age-matched female groups of healthy controls (C) with no history of musculoskeletal problems, TE patients with local tenderness at the lateral epicondyle and pain with resisted wrist and middle finger extension, and RTE cases who were asymptomatic for at least 6 months. Measurements included metacarpophalangeal (MCP) (extension and flexion), wrist (extension and flexion), shoulder (internal rotation, external rotation, and abduction) and grip strength, total upper limb strength and EMG measures of muscle fatigue and activity for five forearm muscles including wrist extensors and flexors.
RESULTS: Strength was greater ($p< 0.05$) for all measurements (MCP flexion 18-21%, grip 15-17%, wrist extension 16-19%, wrist flexion 18-21%, and shoulder 14-20%) in C compared to RTE and TE except for MCP extension. The total upper limb strength was significantly higher in C (122±22) than in both RTE (78±21) and TE (68±15) on the affected side ($p < 0.05$). Interestingly, there was no difference in any of strength measurements between TE and RTE groups. EMG revealed increased activity of ECR in RTE (9±5 %/min) while it was decreased in TE (–12±4 %/min).
In this study, we highlighted activation imbalance, disuse-deconditioning syndrome, and consequent global upper limb weakness in RTE. These findings suggest that regular EMG and strength measurement may provide useful information on recovery progress in the early post-injury stages, when it would be unsafe to perform some sport activities. That no difference was found for any upper limb strength measurements between RTE and TE suggests that there is sustained muscle dysfunction and weakness in RTE despite substantial pain diminutions, possibly because of inappropriate and insufficient rehabilitation. Increased activity of ECR in RTE may be attributable to relative recovery of muscle from injury and consequent reduction in the level of pain.
It is very important not only that attention is paid to pain reduction, but also to objective outcome targets in muscular strength and functional performance. More research is essential to characterize “full recovery” in both its symptomatic and functional dimensions, to assist in establishing an appropriate set of outcome criteria and related measures.
CONCLUSIONS: Appropriate reconditioning of hand-wrist-forearm-shoulder musculature may be essential to achieve full recovery and prevent further tendon overload, degeneration, or relapse. Future studies should provide evidence in support of further rehabilitation after the pain has disappeared. Further research, using large sample sizes, is

needed to investigate the practical reliability of our method in monitoring functional recovery in TE as well as other tendinopathies.

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MUSCLE FUNCTION INVESTIGATED WITH SURFACE ELECTROMYOGRAPHY IN LATRAL ELBOW TENDINOPATHY

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AIM: Lateral elbow tendinopathy or tennis elbow (TE) is the commonest elbow problem in athletes which involves the common wrist extensor origin, particularly the origin of extensor carpi radialis (ECR). At least 40 conservative treatments have been described but the optimal treatment is unknown due to unknown etiology. Muscle imbalance, an unhealthy functional relationship among the periarticular muscles, particularly between agonist and antagonist groups, has become an important topic in the etiology of painful musculoskeletal disorders. We aimed to investigate strength, fatigability, and activity of upper limb musculature to elucidate the role of muscle imbalance in the pathophysiology of TE.

METHODS: Sixteen patients clinically diagnosed with tennis elbow were compared with sixteen control (C) subjects with no history of upper limb musculoskeletal problem. Electromyographic activity (RMS amplitude) and fatigue characteristics (median frequency slope) of five forearm and two shoulder muscles were measured during isometric contraction at 50% maximum voluntary contraction using surface electrodes. Maximum isometric muscle strength was also measured for grip, metacarpophalangeal, wrist, and shoulder on both sides.

RESULTS: All strength measurements showed dominance difference in C (11% for grip, 12% for wrist extension and flexion, and 10–15% for shoulder), but none in TE. In tennis elbow compared to controls, grip (25%), wrist (30%) and shoulder (25–35%) strength were significantly ($p<0.05$) weaker than those in C. Although for most forearm muscles RMS increased with time in both groups, the activity of ECR was markedly reduced ($p<0.05$) in TE group. To consider the importance of kinetic chain principles, we integrated strength and EMG measures in multiple segments of upper limb. A global upper limb weakness was found which needs to be addressed in prevention and treatment strategies for TE. In other words, this suggests that whole upper limb should be included in TE rehabilitation. We were able to identify a muscle activation imbalance (in ECR) in TE that, if not corrected, would result in a widespread imbalance through whole upper limb.

CONCLUSIONS: We suggest that restoration of normal ECR activity should be a treatment goal in the rehabilitation of TE. Although numerous exercises are proposed for wrist extensor and flexor muscles, future work should address which exercises best restore muscle balance rather than muscle strength per se.

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MOTOR LEARNING BY VISUAL AND FES FEEDBACK

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AIM: In this paper, we aim to develop new training system by using not only visual feedback also muscle stimulation (FES: Functional Electrical Stimulation). Because only visual feedback signals does not feed clear information about force. On the other hand, FES activate muscle and generate movement without voluntary command, and somatosensory feedback may affect the brain directly. Also we confirm that the timing of each feedback signal is important or not.
METHODS: The movie and EMG signals were measured simultaneously for teacher signals. Then this video, FES which activities were produced by the EMG signals, or both feedback were applied to the subject. After the training experiments, EMG signals were measured and compared to the teacher signals. In order to confirm that the effect of timing between visual and FES feedback, the time delay between -400 msec and 200 msec was applied.
RESULTS: Table 1 shows the error rate using visual feedback as a normal. FES feedback was slightly effective comparing to only visual feedback condition. All subject reduced the error on the case of both visual and FES feedback and were most effective.
Figure 1 shows the std deviation of EMG signals. All subjects tended to reduce error in -200 msec time difference case except subject D.
CONCLUSION: Visual feedback is usually used for training. And to improve the ability, we learn the skill by trial and error. FES is one candidate for training without visual feedback and somatosensory signals would be effective. In this paper, we confirm that both visual and FES feedback were most effective for learning and also we found that those timing was also important.
ACKNOWLEDGEMENT: This work was done by collaboration between NTT Energy and Environment System Lab and Tokyo Institute of Technology.

Table 1: Error rate comparing proposed method to conventional visual FB.

Subject	Visual FB	FES FB	Proposed Methods
A	1	1.356	1.132
B	1	0.525	0.801
C	1	0.826	0.799
D	1	0.934	0.791

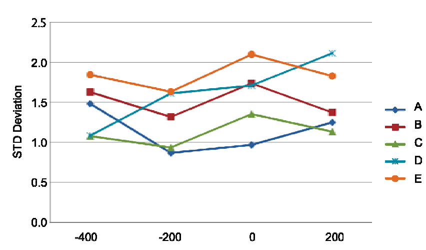

Figure 1: Movement error by using different time difference.

FORWARD LUNGE ANALYZED BY INVERSE DYNAMICS, ELECTROMYOGRAPHY AND COMPUTATIONAL MODELING

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AIM: The goals were to a) review results from previous biomechanical analyses of the forward lunge movement and b) give examples of how electromyography (EMG) and biomechanical/computational methods can be used in synergy to improve the interpretation of the results of the movement analyses.
METHODS: We have studied the biomechanics of the forward lunge movement in several cases and for different purposes. The focus has primarily been on the knee joint. The joint kinematics and kinetics were quantified by using an inverse dynamics approach. The calculations were based on motion capture of markers placed on the lower extremities and ground reactions forces recorded by a force platform. The study subjects were instructed to perform a forward lunge onto the force plate targeting a knee flexion angle of 90° and subsequently extend the knee to return to the starting position. In addition, surface EMG was recorded from the knee joint flexor and extensor muscles. Experimentally induced m. vastus medialis pain was used to investigate how pain influenced the muscle function and hence the biomechanics and EMG activity during the forward lunge. Recently, a musculoskeletal model of the forward lunge was established to computationally investigate the biomechanics and especially the mechanical function of the ACL during this movement. The marker trajectories obtained experimentally were processed by means of an optimization algorithm in order to determine the movement pattern and scaling of the model segments to fit the experimental data accurately. The force plate data were processed to determine the moving centre of pressure and ground reaction force vector, which were subsequently applied to the feet. Experimentally recorded EMG was used to validate this model.
RESULTS: The experimentally derived biomechanical variables were supported by the EMG measurements. Furthermore, as net joint moments do not give information about the degree of co-contraction during the forward lunge movement, the EMG results improved the interpretation of the biomechanics by quantifying the activity of specific knee joint flexor and extensor muscles during the movement. This had implications for explaining the observed movement patterns in different groups of subjects. Experimentally induced muscle pain reduced the EMG activity in quadriceps, which decreased the knee joint moment confirming that local pain was capable to alter the knee joint and quadriceps function in a dynamic situation. Computational modeling of the forward lunge enabled the possibility to calculate the individual muscle forces. This is challenging and demands validation. Experimentally recorded EMG was used for that purpose and showed that the timing and level of activity was fairly the same as the muscle activities observed in the model.
CONCLUSION: These studies have shown that the use of EMG in combination with biomechanical/computational methods adds information to the movement analyses and improve the interpretation of the results.
ACKNOWLEDGEMENT: These studies were performed in collaboration with Erik B. Simonsen, Poul Dyhre-Poulsen, S. Peter Magnusson, Henrik Aagaard, Marius Henriksen, Henning Bliddal, Maja R. Wieland, Michael S. Andersen and John Rasmussen.

THE APPROXIMATE ENTROPY OF ELECTROMYOGRAPHIC SIGNALS CORRELATES WITH AGE

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AIM: The main aim of this study was to verify the correlation between electromyographic (EMG) signals and ageing by means of the estimated Approximate Entropy (APen) of signals.
METHODS: In total 59 clinically healthy subjects, i.e., without evidences of suffering from neurological disorders participated of this investigation. The age range of the participants was from 20 to 86 years. During the experiment subjects were asked to use a laser pointer to follow an Archimed's spiral trajectory inwards and outwards. They were oriented to execute this task at a natural speed. The muscle activity was also measured at rest with subjects maintaining the laser pointing towards the centre of the spiral for 30 s. The signals were detected by means of Ag/AgCl surface EMG sensors positioned on the extensor digitorum communis muscle of the subject's dominant hand. The APen of EMG signals were estimated for both the dynamic and static conditions and the correlation between the APen and age was investigated.
RESULTS: The results showed that there is a positive correlation between the APen of EMG signals and age for both the static and dynamic conditions (r^2 = 0,9023 and r^2 = 0,8085, respectively), as shown in Figure 1.
CONCLUSION: This study showed that there is a linear correlation between the APen of EMG signals and age for both the static and dynamic experimental conditions. These results can be potentially employed as tool for discriminating healthy from pathological individuals.
ACKNOWLEDGEMENTS: The authors would like to thank the Brazilian government for supporting this study (Project PPSUS/FAPEMIG 2006 Nr. 3300/06).

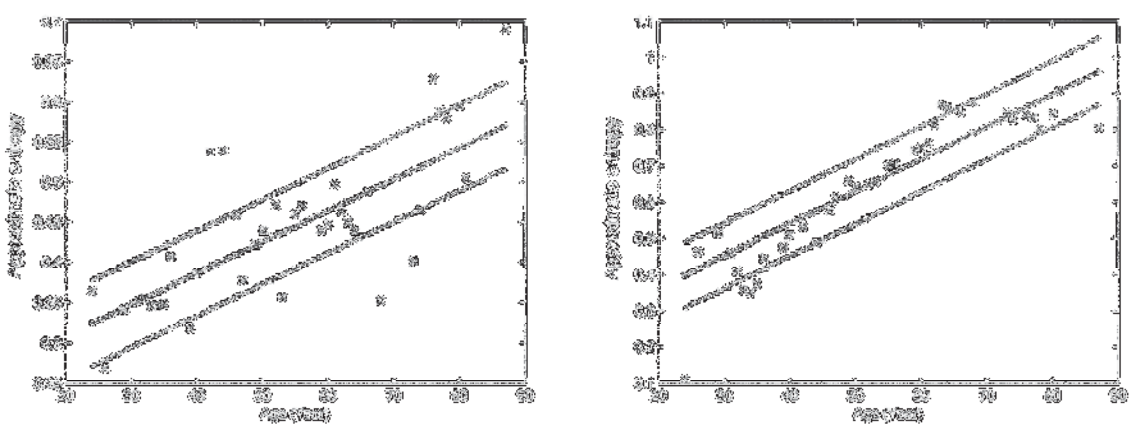

Figure 1: A linear model fit (solid line) showing the linear relation between the Approximate Entropy of EMG signals and age. The dotted lines are the 95% confidence interval of the model. The results at the left are for the dynamic condition whereas at the right for the static condition.

IMPROVEMENT OF COGNITIVE FUNCTION AFTER BILATERAL PREFRONTAL TRANSCRANIAL DC STIMULATION IN HEALTHY ELDERLY

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AIM: Noninvasive transcranial direct current stimulation (tDCS) can modulate the cortical excitability and has been applied for improvement of brain functions. We investigated the effects of bilateral prefrontal tDCS in healthy elderly by means of verbal and visual working memory tasks.
METHODS: Fifteen healthy elderly (9 males, 6 females, and mean age 70.7) were enrolled in this study. A sham controlled, double-blind and cross-over study was conducted. Subjects underwent three experimental sessions, 1) sham, 2) anodal DC over left prefrontal (F3), and 3) dual anodal DC over bilateral prefrontal (F3&F4 in 10-20 EEG system) cortices. DC was delivered for 20 minute at 2 mA with 25 cm^2 saline-soaked sponge electrodes. Cathode electrode was applied on left arm. Before and after tDCS, subjects were performed 2-back verbal working memory and visual memory tasks. The improvement rate of the accuracy and the reaction time after three sessions were analyzed using ANOVA and post-hoc t-test.
RESULTS: In 2-back verbal working memory task, the improvement rate of accuracy was significantly higher after bilateral prefrontal tDCS (8.2%) than sham (-0.2) (P=0.04), the improvement rate of reaction time was also significantly higher after bilateral prefrontal tDCS (7.9%) than sham (-2.1%) (P=0.01). In visual working memory task, the improvement rate of reaction time was significantly higher after single left prefrontal tDCS (13.6%) than sham (-0.1%) (P=0.01) and bilateral prefrontal tDCS (13.7%) than sham (P=0.02).
CONCLUSION: The results showed beneficial effects of noninvasive transcranial anodal DC stimulation on cognitive function in healthy elderly. Especially, the bilateral prefrontal anodal tDCS can be more effective method to improve working memory. We suggest that tDC-induced changes in neural excitability could be provide an adjuvant treatment tool for facilitating cognitive function in elderly population.

DETECTING NEUROMUSCULAR DISEASE AND ITS LEVEL OF INVOLVEMENT USING MOTOR UNIT POTENTIAL CHARACTERIZATIONS

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AIM: Sets of motor unit potential (MUP) characterizations are aggregated to produce a muscle characterization to detect the presence and measure the level of neuromuscular disease [1]. The accuracy and correlation with level of involvement (LOI) of several MUP characterization and aggregation methods were evaluated.
METHODS: MUP characterizations were obtained using several classification methods: Naïve Bays (NB); linear discriminant analysis (LDA MED and LDA GED); and pattern discovery (PD) [1]. Muscle characterizations were obtained by aggregating MUP characterizations using: the arithmetic mean (AMC), Bayes rule (BMC), the 'centroid' of the ‘winning’ MUP characterization scores for each category (CMC), and the count ratio of the ‘winning’ MUP characterization scores for each category (NMC). Muscle characterization performance was assessed using accuracy as well as its mean absolute deviation (MAD). Spearman's correlation coefficient was used to assess the correlation between the muscle characterization measures and the LOI.
RESULTS: In total, 320, 360 and 360, normal, myopathic and neurogenic MUPs, respectively, were extracted from simulated EMG signals [2]. The sets of myopathic and neurogenic MUPs were comprised in equal proportions of MUPs detected in muscles modeled to have 25%, 50% and 75% LOI, respectively (i.e. muscle fiber/motor-unit loss). Fifty virtual muscles of each category (350 in total) were represented by sampling twenty MUPs from a given pool without replacement. Using the LDA MED classifier and BMC achieved the highest mean accuracy across all muscle pools at 82%, and the lowest MAD value at 0.6% as well as a good overall balance in accuracy across the various LOIs for each category. With comparable accuracy (76 – 80%), PD had MAD values of 10, 9, 4 and 5 % for the AMC CMC, NMC and BMC aggregation methods, respectively. The highest mean correlation with LOI was achieved using AMC with the NB or LDA GED classifiers (0.94). PD performed comparably with correlation values of 0.91, 0.89 and 0.91 for the AMC, CMC and NMC methods, respectively. Correlation values using BMC were quite poor in general (0.27-0.49).
CONCLUSION: The results suggest that suitable muscle characterization measures that maximize accuracy and correlation with LOI can be obtained. The best way to optimize both accuracy and LOI correlation is to use separate metrics, BMC-based measures for accuracy and AMC-based measures for correlation to LOI. Such muscle characterization measures could make it possible for a clinician to both accurately detect a neuromuscular disorder as well as track its progression using QEMG and the techniques presented herein.
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LUMBAR SPINE KINEMATICS AND TRUNK MUSCLE ACTIVATION IN STOOP AND SQUAT LIFTERS DURING REPETITIVE LIFTING AND LOWERING TO FATIGUE.

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AIM: Lifting posture and fatigue are known risk factors for low back injury. However, few studies have investigated the influence of posture on lumbar spine motion and associated trunk muscle activity during highly repetitive lifting. Hence, the purpose of this study was to investigate lumbar spine kinematics and trunk muscle activation in stoop and squat lifters during repetitive lifting and lowering to fatigue.
METHODS: Eight stoop and 12 squat lifters were classified from a group of 35 male subjects who were required to lift and lower a 13 kg box using a self-selected posture 20 times per minute until fatigued. Sagittal lumbar kinematic measures (lumbar angle and angular velocity) were derived from motion analysis data using two pairs of markers located on the sacrum and L1-2. Trunk muscle EMG from upper and lower erector spinae, rectus abdominis, and the internal and external oblique muscles were also collected and expressed as a percentage of maximal activation. Kinematic and EMG measures were quantified for the start, middle and end of the lifting and lowering phases, at the beginning and end of the fatiguing task.
RESULTS: Stoop lifters flexed their lumbar spine close to 100 percent of maximal flexion and generated lumbar extension and flexion velocities that were three times greater than that exhibited by squat lifters ($P<0.05$). Upper erector spinae muscle activation was similar for both groups peaking during the start of the lift and end of lowering. Lower erector spinae activity differed between postures with maximal activation in stoop lifters peaking in the middle and final stages of the lift when lumbar angular velocity was at it greatest. In contrast, lower erector spinae activation levels in squat lifters were maintained during lifting and progressively increased during lowering. Internal oblique was the most active abdominal muscle during the task ($P<0.05$). At the end of the task stoop lifters significantly reduced the velocity and extent of lumbar extension ($P<0.05$). Both groups increased co-activation of all abdominal muscles and upper erector spinae when fatigued ($P<0.05$).
CONCLUSIONS: The increased spinal flexion and lumbar velocity associated with stoop lifting may place stoop lifters at a greater risk of spinal injury. These findings, coupled with the levels of muscle activation of stoop lifters support anatomical evidence that lower erector spinae may function differently to upper erector spinae during activities which use a large range of lumbar motion. It would appear that irrespective of posture, abdominal and upper erector spinae co-activation may be a mechanism to aid spinal stability when fatigued.
ACKNOWLEDGEMENT: New Zealand Society of Physiotherapists

MOTOR PERFORMANCE IN CHRONIC LOW BACK PAIN

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AIM: Management of chronic low back pain (CLBP) is difficult because of insufficient knowledge about the mechanisms how chronic pain is developed and maintained. Starting from the generally accepted biopsychosocial model of chronic pain, the physical aspects of CLBP seem to be one of the necessary aspects that needs to be explored. The aim of this study is twofold. One to investigate whether there is a deviation in daily activity patterns in CLBP patients and two to investigate whether CLBP patients show deviations in trunk muscle activity during walking on a treadmill. Both when compared to a-symptomatic controls.

METHODS: Two cross-sectional studies were performed. In study 1, sixty-three subjects with CLBP and thirty-three a-symptomatic controls walked on a treadmill at different velocities. Surface EMG data of the erector spinae -, rectus abdominis- and obliquus abdominis externus muscles were obtained and averaged per stride and expressed in SRE values. In study 2, 29 CLBP patients and 20 controls wore a tri-axial accelerometer for seven consecutive days during waking hours to assess their daily activities. These signals were filtered and averaged to obtain an activity level per hour.

RESULTS: Study 1 showed that for both the back and abdomen muscles the mean SRE values were significantly higher in subjects with CLBP than in controls both during periods of double support and swing[2]. In addition, results show that in the back muscles the alteration in muscle activity between periods of swing and double support is not different between both groups[1].

Results of study 2 show that the total amount of activities on a day is not significantly different from those of controls. However, patients show a deviating trend over the day with significantly higher activity levels in the morning ($p<0.001$) and significantly lower activity levels in the evening ($p<0.01$) compared to controls[3].

CONCLUSIONS: Based on these results, it can be concluded that patients with chronic low back pain show altered physical performance during every day life which is reflected in a muscle guarding of back and abdomen muscles during walking as well as a decline in daily activity patterns over the day. This knowledge can be used as starting points for the development of a new treatment approach involving monitoring and feedback on their daily performance.

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EMG-FORCE RELATIONSHIP: PRELIMINARY DATA ON LOAD SHARING

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AIM: The relationship between the contribution to joint torque T and EMG produced by a muscle is an open research issue. Most researchers agree that such relationship is monotonic and approximately linear or slightly convex. For each muscle m we propose the model $T_m = W_{1,m} V_m^{W_{2,m}}$ where V_m is the EMG envelope obtained as the low pass filtered spatial average of the rectified values of bipolar EMG channels obtained from an electrode array covering the muscle's surface. The linear and exponential weights $W_{1,m}$ and $W_{2,m}$ can be estimated as the values that minimize the MSE between the model equation and the experimental curve $T_m = f(V_m)$. Assuming that N muscles act on a human joint, the total torque is the summation $T_t = \Sigma^{N}_{m=1} (W_{1,m} V_m^{W_{2,m}})$. 2N weights will have to be estimated from one experimental torque plot T_e and N EMG signals V_m. The Interior-Reflective Newton algorithm was adopted for functional minimization of $e^2 = (T_e - T_t)^2$ (Coleman T., Y. Li, SIAM J. on Optim. 1996;6:418-445 and Math. Programm., 1994;67:189-224). The 2N-dimensional error function has multiple and shallow minima. This work investigates this approach for estimating the elbow torque produced by the flexors and extensors acting on the joint. The physiological meaning of multiple solutions will be considered.
METHODS: Two elbow flexors (biceps brachii and brachioradialis) and two extensors (lateral and medial head of triceps brachii) were considered. A 2D array with 13 x 5 electrodes with inter-electrode distance (ied) = 8mm was applied on the biceps brachii and a linear array of 8 electrodes (ied= 5mm) was applied on each of the other three muscles. Three different torque ranges (0±30%, 0±50%, and 0±70% of the maximal flexion and extension) were tested in four subjects in isometric conditions (right elbow at 90°). Boundary conditions were set for estimated muscle forces (only pulling), and for the starting values of $W_{1,m}$ and $W_{2,m}$. As expected, more than one set of weights could lead to the same total force. The W_2 values were initialized in the range 0.1-0.5 while the W1 values were initialized in a range depending on the peak values of the V_m signals. After the phase of weight identification the torque contribution of each muscle m could be estimated on the basis of $W_{1,m}$ and $W_{2,m}$ for subsequent ramps.
RESULTS: Estimated torques matched very well the experimental torques. Different initializations lead to slightly differently localized minima (different forms of load sharing). Neglecting the brachialis (a deep muscle) and part of the triceps implies errors that are not yet quantified.

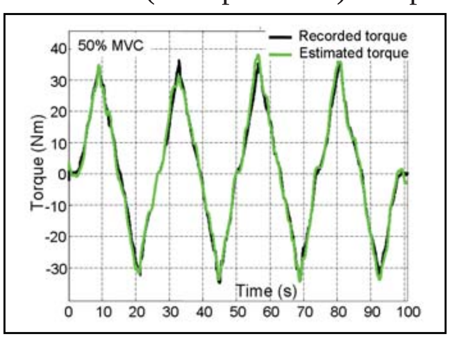

Figure 1: Recorded torque (black) and torque estimated from EMG (green) exerted by a subject during a 50%MVC flexion-extension isometric ramps. Relative error of force estimation is (8.3 ± 0.0)% (N = 10 different initializations within an optimal initialization region). Estimated weights are (mean ± st.dev.) W_1 =4.39 ± 0.25 and W_2 =0.34 ± 0.01 for biceps brachii, W_1 =7.15 ± 0.8 and W_2 = 0.31 ± 0.02 for brachioradialis, W_1 = -9.23 ± 0.92 and W_2 = 0.30 ± 0.02 for lateral head of triceps brachii, and W_1 =-0.25 ± 0.09 and W_2 = 0.82 ± 0.05 for medial head of triceps brachii. These weights could be a first step for addressing the problem of load sharing evaluation.

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CHARACTERIZATION OF PERI-INFARCT, INTRA-CORTICAL M1 RESPONSES IN AN ANIMAL MODEL OF ISCHEMIC STROKE

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AIM: In the US alone, approximately 700,000 new incidents of stroke occur annually and about 75% survive with some degree of disability (www.nih.gov). Neuroplasticity is believed to play a key role in functional recovery. Placement of micro-electrode arrays in the cortical tissue has not traditionally been used to evaluate the direct, intra-cortical response following brain injury such as stroke. This work is part of ongoing efforts in our lab to investigate cortical neuroplasticity using intra-cortical recordings in an animal model of ischemic stroke. The objective of the present work was to characterize short-term changes (<8 hrs) in the intra-cortical responses from the primary motor cortex in an animal model of ischemic stroke.
METHODS: Nine acute experiments were performed (3 control and 6 infarcts). We instrumented the animals with a 4 x 4 channel tungsten micro-wire array (100 µm wire diameter, ~500 µm inter-electrode spacing) in the primary motor cortex (M1) and a bipolar cuff electrode (length ~10 mm, diameter ~2 mm) around the ulnar nerve in the contra lateral forelimb. M1 were responses recorded before, during and after a cortical ischemic infarct, while the ulnar nerve was electrically stimulated. A 3 mm ischemic infarct was created immediately posterior to the electrode array by activating a photosensitive dye (Rose Bengal, 1.3 mg/100 mg body weight). The peri-stimulus time histogram (PSTH) responses were generated. We extracted 11 features to reflect changes in the cortical excitability over time.
RESULTS: We found that the decrease of the cortical responses was dependent on the distance from the ischemic core. The peak firing rate and the peak-latency time of the cortical peri-stimulus time histograms (PSTH'es) were found to reflect changes in the cortical excitability over time robustly (see Figure 1 and Figure 2). We observed variability across animals should be expected and must be investigated further. The extracted features reflected periods of hyperexitability, cessation of response and increased response latency to electrical stimulation.
CONCLUSIONS: An intricate understanding of the neuroplastic changes in both acute and chronic animals may assist in optimizing acute stroke therapies and optimize functional recovery further.

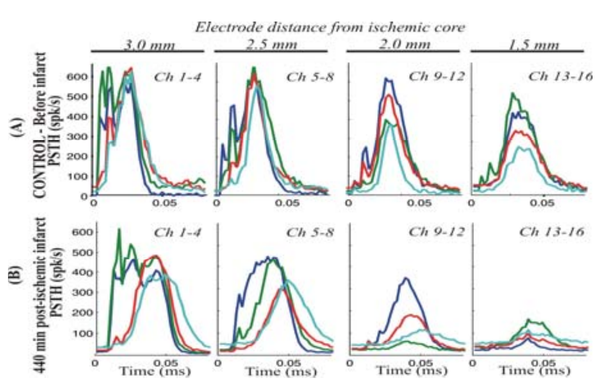

Figure 1: Change in peak activity for one control animal (A) and one animal experiencing an infarct (B).

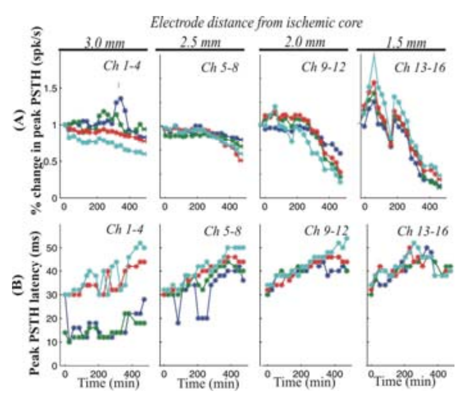

Figure 2: Change in peak activity (A) and peak-latency (B) relative to the pre-infarct activity in one animal.

TRANSVERSE INTRAFASCICULAR MULTICHANNEL ELECTRODE (TIME) SYSTEM FOR TREATMENT OF PHANTOM LIMB PAIN IN AMPUTEES

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AIM: Phantom limb pain (PLP) develops in the lost limb in 50-80% of amputees. Today, it is not completely understood why the pain occurs, and no effective treatments are available. The favorable effect of electrical stimulation on PLP has been demonstrated. Our aim is to develop a novel system for manipulation of sensations by application of multi-channel microstimulation to the nerve stump of an amputee and explore this method as a treatment for clinched fist PLP (see figure).
RESULTS: 1) Electrode design. Non-corrugated TIME electrodes with different dimensions and 8-12 active sites have been manufactured and tested in vivo and in vitro in the rat and pig animal models. Methods for corrugated prototypes were developed and realized. 2) Electrode selectivity modeling. A peripheral nerve model is under development to evaluate the electrode's selective stimulation properties and to optimize electrode design. Simulated currents and neural activity generated were qualitatively assessed using experimental data obtained from rat nerves. 3) Implant modeling. To optimize the implantation procedure, a theoretical peripheral nervous tissue model and a 3D FEM was implemented. Both models closely reproduce the experimental peripheral nervous tissue behavior and simulate the insertion forces transmitted to the electrode during implantation. 4) Multi-channel stimulators and connectors. A 12-pole bench-top, prototype stimulator has been implemented and successfully tested in animal experiments. A high-count, implantable connector between stimulator and electrode has been designed. 5) Biocompatibility. Electrode materials were evaluated and did not induce immune rejection and significant inflammatory reaction after in vivo implantation in the rat. Electrode implantation will require an understanding of the fascicular characteristics of the target nerve. Morphological characteristics of the rat, pig and human nerves are currently evaluated and compared.6) Animal testing. First TIME electrodes test were carried out in the acute rat and acute pig animal models. Results indicated selective stimulation of different fascicles with graded recruitment. 7) Clinical evaluation: To quantify the location of artificially evoked sensations and evaluate the strength of artificially evoked sensations a psychophysical testing platform is under development. The main inclusion criteria for patient recruitment have been identified and protocols have been defined.
CONCLUSION: The feasibility of the corrugated version of the TIME electrode has yet to be explored. Further work designing, optimizing and testing the TIME electrode and all technological developments will be carried out including theoretical stimulations and animal experimental work before the optimal electrode for human implant will be chosen.
ACKNOWLEDGEMENTS: Funded by FP7 - ICT-2007.3.6, 224012 (www.project-time.eu)

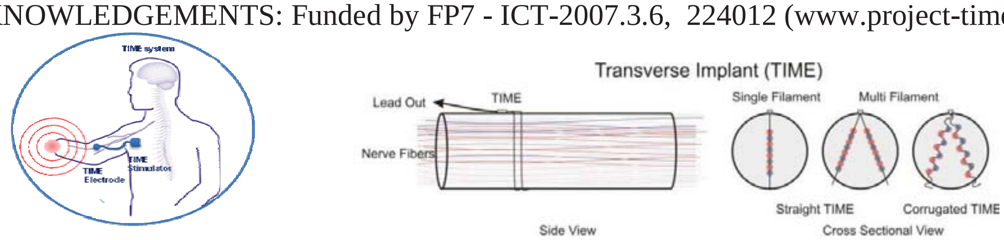

Figure 1: Concept of project TIME (left) and the concept of TIME electrode (right)

DOES TIMING TRAINING INFLUENCE THE GOLF-SWING PERFORMANCE?

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AIM: According to professional golfers (e.g. Watson, 1998), instructors (e.g. Pelz & Frank, 1999), and scientists (e.g. Neal et al., 2008), precise timing are considered to be crucial for performing an optimal golf-swing. Recent findings from timing based intervention by use of synchronized metronome training (SMT) have reported improved golf shot accuracy (Sommer & Rönnqvist, 2009). However, no studies have investigated the effect of SMT on the spatiotemporal properties of the golf-swing. Thus, the present study was designed to investigate whether extensive SMT may affect the kinematics of the golf swing performance. Additionally, by analyzing the spatiotemporal properties and the intra- and inter-limb couplings of selected upper-body-club movements, further understandings of the timing concept of the golf-swing are expected.

METHODS: Thirteen experienced male golfers participated (mean age 27.5 years; mean golf handicap 12.7). The golfers completed a 4-week SMT program designed to improve their motor-timing. No golf practices were made during the training period. Pre- and post-test investigations were completed of the golf-swing performance made by three different golf-clubs. Measurements of respective shoulder, elbow, wrist and the golf-club movements were made by use of a 3D motion registrations system (ProReflex), and further subjected to biomechanical analyses of the spatiotemporal characteristics involved.

RESULTS: The relative durations of the golf-swing phases (backswing; downswing; follow-through), and the total duration of the golf-swing, was found to be highly consistent (invariant) over tests and clubs. However, a significant and rather consistent finding was the higher cross-correlation values of the intra- and inter-joints couplings at the post-test in comparison to the pre-test (Fig 1). A concomitant significant change in the corresponding phase shifts from zero-lag at maximum cross-correlations was also found.

CONCLUSION: This finding suggests that the synchronized metronome training accentuate the coordinative structure and the temporal synchrony between the intra- and inter-limb couplings and the golf-club motions. Together, the data indicate that improved motor-timing may affect the temporal properties of the upper-body motions of golf-swing performance while the golf-swing tempo seems relatively unaffected by the SMT.

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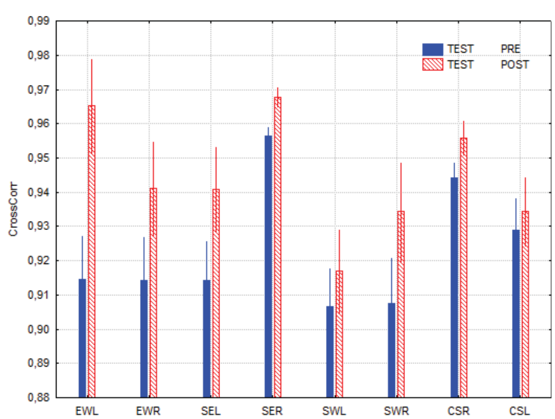

Figure 1: Mean maximum cross-correlation (r_{max}) as a function of test (pre- and post), and joint couplings (E=elbow, W=wrist, S=shoulder, C=clubhead, L=left, R=right).

SIZE DOES MATTER: THE INFLUENCE OF MOTOR UNIT POTENTIAL SIZE ON STATISTICAL MOTOR UNIT NUMBER ESTIMATES IN HEALTHY SUBJECTS

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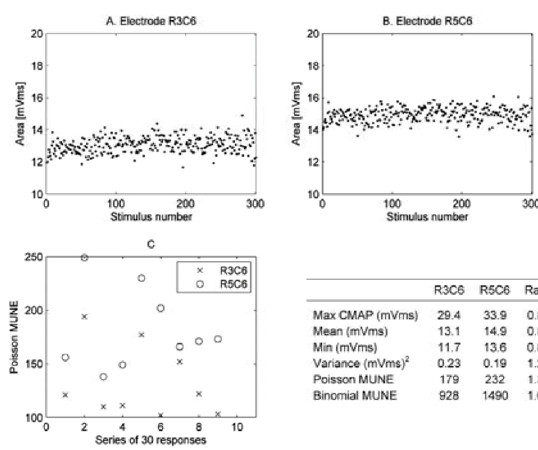
AIM: The number of motor units in a muscle can be estimated by dividing the maximal compound muscle action potential (CMAP) by a mean MUP. The statistical method of motor unit number estimation (MUNE) assumes that all motor unit potentials (MUPs) have the same size. The present study aims to evaluate the consequences of this assumption as well as its implications for the validity of statistical MUNEs.
METHODS: We performed statistical and multiple point stimulation (MPS) MUNE with an array of 120 electrodes on the thenar muscles of 15 healthy subjects. Statistical MUNE uses the effect called alternation to determine the average MUP size. High-density MPS MUNE uses near-threshold stimulation to obtain single MUPs and averages these MUPs to obtain the mean MUP. These high-density EMG recordings allow isolation and quantification of the effect of non-uniform MUP size on MUNE, because the differences in submaximal CMAP size (and, hence, in MUNE) between electrodes are due almost entirely to differences in (summed) MUP size. MU fingerprints are determined to a large extent by the spatial characteristics of the MUs and tend to be very different from each other. Summations of MUPs, can, therefore, result in CMAPs that have very different waveforms and amplitudes even between electrodes that are less than a centimetre apart.
RESULTS: We found no correlation between statistical and MPS MUNEs. Statistical MUNEs proved very sensitive to small variations in the “bandwidth” (variance) of the response series (Fig. 1); MUNEs from electrodes only 8 mm apart could deviate by as much as 60%. This variation in bandwidth resulted from spatial (and, hence, size) differences between the contributing MUPs.
CONCLUSION: Our study indicates that the statistical MUNE method cannot derive a valid motor unit number in healthy subjects. The method is very sensitive to violation of the uniform MUP-size assumption, to an extent that blurs any correlation with MPS MUNE. This sensitivity is likely to get worse in conditions of mild to moderate motor unit loss. This suggests that statistical MUNE cannot be used in these conditions either.



	R3C6	R5C6	Ratio
Max CMAP (mVms)	29.4	33.9	0.87
Mean (mVms)	13.1	14.9	0.88
Min (mVms)	11.7	13.6	0.86
Variance $(mVms)^2$	0.23	0.19	1.21
Poisson MUNE	179	232	1.30
Binomial MUNE	928	1490	1.61

Figure 1: A and B: submaximal CMAP sizes from nearly adjacent electrodes (8 mm apart). C: resulting MUNEs per series of 30 responses for both electrodes. Bottom right: characteristics of the two response distributions. Values derived from the full data set of 300 stimuli (no subdivision in series)

EVALUATING THE MOTOR UNIT NUMBER INDEX (MUNIX) AS A MEASURE FOR MOTOR UNIT LOSS

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AIM: With the increased number of potentially therapeutic agents, monitoring of motor neuron loss in patients is of great importance. Functional measures are masked by motor neuron loss because of collateral reinnervation. Thus, a more direct measure is required. In this study, we evaluate a recent technique called MUNIX to determine motor neuron loss.
METHODS: A model was constructed to study the effect of denervation and collateral reinnervation on surface motor unit potentials (MUPs). A small muscle containing 200 motor units was simulated. The process of motor neuron denervation is simulated by removing one motor neuron at a time leaving all its fibres orphaned. As muscle fibre loss after denervation is counteracted by reinnervation, the orphaned fibres could be reinnervated by a motor unit (MU) with a fibre adjacent to this fibre. MUNIX is calculated from the surface interference pattern (SIP) together with the maximal compound muscle action potential (CMAP) as described by Nandedkar et al. (2003). SIP area and SIP power are calculated for five levels of contractions. The "ideal case motor unit count" (ICMUC) is defined as $\mathrm{ICMUC} = \frac{\mathrm{CMAPpower} \cdot \mathrm{SIParea}}{\mathrm{CMAParea} \cdot \mathrm{SIPpower}}$. The ICMUC provides the real number of MUs if all MUs would be equal in size and no phase cancellation would occur. Since this is not the case, the relation between ICMUC and SIP area is determined as $\mathrm{ICMUC} = \mathrm{B}(\mathrm{SIParea})^{\alpha}$,where B and α are determined by means of nonlinear regression and MUNIX is calculated as $\mathrm{MUNIX} = \mathrm{B}(20)^{\alpha}$. To test how well this method can follow motor neuron loss, we used the above denervation model. A MU firing pattern was generated based on the model of Matthews et al. (1996). The size principle (Henneman) was applied creating the surface interference patterns, so that small MUs (i.e. small number of fibres) are recruited before large MUs. Small MUs also had a lower firing rate than large MUs.
RESULTS: The MUNIX and CMAP results were evaluated in steps of 5% MU loss. We used different firing patterns and slightly different contraction levels (i.e. number of MUs) per run to obtain a measure of variability. Figure 1 shows that the MUNIX (blue) does not significantly decline until at least 40% of all MUs are lost and seems strongly related to the change in the CMAP amplitude (red).
CONCLUSION: This preliminary simulation study shows that MUNIX follows motor neuron loss somewhat better than CMAP amplitude. The results after severe denervation should be interpreted with care as it is likely that the model is incorrect at that point.

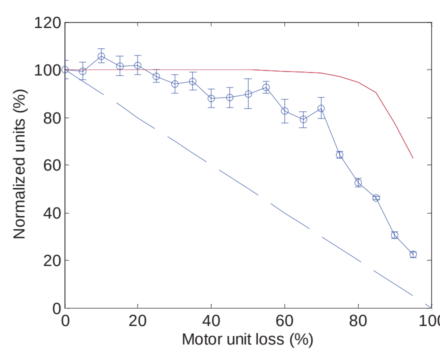

Figure 1: CMAP (red solid line) and MUNIX (blue line with SD error bars) vs percent motor unit loss. The dotted line indicates the number of MUs (normalized to 100%).

THIN-FILM ELECTRODES FOR MULTI-CHANNEL INTRAMUSCULAR EMG RECORDINGS IN HUMANS

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AIM: To develop electrodes based on thin-film technology with multiple detection sites for intramuscular EMG recordings in humans. Currently used intramuscular electrodes allow extracting only a very limited number of motor units from the muscle fibers surrounding the detection point. The rationale behind the design of a multi-channel thin-film intramuscular system is to combine spatial sampling and selectivity for investigating concurrently a large population of motor units during voluntary contractions. The thin-film technology has been applied in nerve recordings and intramuscular recordings in animal preparations (Farina et al. 2008). However, there are currently no applications to intramuscular recordings in humans.
METHODS: The electrodes were fabricated using microtechnology processes. A 5 µm thick polyimide layer was deposited on a silicon wafer by spin coating. 300 nm thick metallic layers of gold and platinum for the electrode contacts, tracks and contact pads were sputtered on the polyimide and patterned by a lift-off process. Subsequently, a second 5 µm polyimide layer was spin coated, and the electrode contacts and contact pads were opened by reactive ion etching. The separated thin-film structures could then be removed from the wafer using tweezers. For contacting, the thin-film electrodes were connected to an FR4 using a modified bonding technique (MicroFlex). A connector was soldered to the FR4. To facilitate implantation, a cannula (width 0.55 mm, length 45 mm) was hooked to the electrode so that the electrode can be inserted with the same procedures as the classic wire intramuscular EMG recordings.
CONCLUSION: An innovative multi-channel thin-film wire system for intramuscular EMG recordings has been devised. This electrodes system introduces a new technology for electrophysiological muscle investigations.
ACKNOWLEDGEMENT: The Obel Family Foundation (DK), Regione Autonoma della Sardegna (IT).

Figure 1: Thin-film electrode system with needle for insertion into the muscle and connector.

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MOTOR MODULES OF LOCOMOTION IN STROKE PATIENTS

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AIM: It has been hypothesized that the coordinated activation of muscles is controlled by the central nervous system (CNS) by means of a small alphabet of control signals and corresponding motor modules (also referred as muscle synergies). The aim of this study was to investigate the modular organization of locomotion in stroke patients.
METHODS: We analyzed the locomotion (free walking, 6-m long trials) of 10 patients (2-6 months post-stroke) and compared it with 10 healthy matched control subjects. Surface EMG signals were recorded from 16 muscles per body side of lower and upper limbs and trunk. Motor modules (muscle synergies) and activation signals (control signals descending from supraspinal centers) were extracted from the muscle activation pattern with non-negative matrix factorization.
RESULTS: Only 4 motor modules were sufficient to explain the majority of the variability in muscle activation patterns in both controls (coefficient of determination: 95.0 ± 2.1 %) and patients (affected side: 97.0 ± 1.4 %; unaffected side: 95.2 ± 3.0 %). In the healthy control group, the motor modules had high similarity between sides (degree of similarity, 0.94 ± 0.04) and among subjects (0.72 ± 0.04). The motor modules extracted from the affected and unaffected side of stroke patients (0.52 ± 0.18) and from different stroke patients (0.50 ± 0.03 for affected side and 0.57 ± 0.06 for unaffected, respectively) showed greater differences. Moreover, it was not possible to reconstruct the muscle activation pattern of stroke patients using the motor modules of healthy controls (average accuracy with 4 modules, 0.39 ± 0.14 for affected side and 0.31 ± 0.11 for unaffected). Despite the differences in motor modules, the activation signals were similar between groups (0.80 ± 0.01 and 0.77 ± 0.04 for affected and unaffected side, respectively) and between the affected and unaffected side of stroke patients (0.75 ± 0.04).
CONCLUSION: Locomotion is organized by a small number of motor modules in healthy subjects and stroke patients. The motor modules observed in healthy subjects, however, are different from those used by stroke patients during locomotion, despite similar activation signals. These results can be interpreted as a misdirection of spinal synergies following stroke.

IMPROVED GAIT INITIATION WITH DEEP BRAIN STIMULATION

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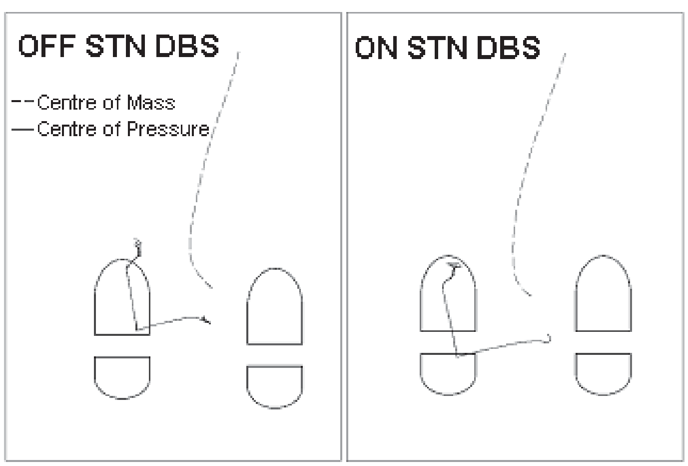
AIM: Gait initiation in Parkinson's disease (PD) is impaired as a result of functional akinesia and has been related to the muscular rigidity but also the unexplained neuronal loss of the pedunculopontine nucleus. Deep brain stimulation (DBS) of the subthalamic nucleus (STN) has shown to alleviate cardinal symptoms and improve gait function. However, the impact of STN DBS on movement initiation has only sparsely been described.
METHODS: Gait initiation was evaluated in 7 PD patients treated with bilateral STN DBS, standing with both feet on a single force plate in ground level, "on" and "off" stimulation, off medication using the Vicon 612 system. Gait was initiated when a visual cue was given. Initiation cycle was defined from cue until second foot strike.
RESULTS: STN DBS improved the timing of events in initiation cycle and length of the first step after initiation cue ($p<0.05$). DBS improved displacement of body mass during initiation (fig.1). OFF treatment, weight was displaced lateral towards the stance limb. ON DBS, weight was shifted postero-lateral towards swing limb heel and the contra-lateral to stance-leg.
CONCLUSION: Forward oriented movement of body mass is a typical sign of PD gait. We address STN DBS influence on gait initiation. DBS enables the patients to shift body load backward and thus initiate motion without propagation.



METHODS AND APPLICATIONS TO IDENTIFY LOCAL MUSCLE FATIGUE DURING MOVEMENTS – SPECTRAL ANALYSIS OF EMG SIGNALS

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AIM: (1) To provide an overview on physiological fundamentals and parameters of EMG-spectral analysis. (2) To introduce two algorithms to analyze dynamic muscle contraction. (3) To demonstrate two applications in which frequency parameters of EMG-spectra were used to detect local muscle fatigue.

FUNDAMENTALS: Aside from geometrical influences, the main physiological parameters determining the EMG power spectrum are muscle fiber conduction velocity (MFCV) and the shape of motor unit action potentials (MUAPs). Depending on different fiber types, spectra range approximately from 10 to 350 Hz.

There are two major electrical effects of local muscle fatigue, that influence EMG spectra: a) A decrease of propagation velocity of the surface action potentials and a shift of muscle fiber type recruitment to slow twitch fibers result in a decrease of MFCV.. b) Amplitude reduction and longer duration of the MUAPs also result in spectral changes to lower frequencies.

ALGORITHM: The Short Time Fourier Transformation (STFT) and the smoothed pseudo Wigner-Ville-Transformation (spWVT) can be applied to non-stationary signals occurring in dynamic muscular contractions. The classical approach of the FFT is not valid for the analysis of these contractions. The instantaneous median frequency (IMDF) can be used as an index of fatigue.

APPLICATIONS: a) Detection of local muscle fatigue during an exhausting lifting test (PILE) (Mayer, 1988). Knee and trunk extensor muscles (v. lateralis VL and erector spinae ES) were analyzed (Fig.1). The ES showed a significant decrease in median frequency while there is no change for the VL (Fig.2). These results correspond to the kinematic changes during the test. b) Analysis of different arm and trunk muscle activation during a specific strength exercise for rowers. Seven female subjects placed in a prone position on a horizontal board repetitively lifted a mass of two third of their one repetition maximum at a fixed frequency of 0.5 Hz until complete exhaustion. The results showed various levels of fatigue for different muscles. Combined with EMG amplitude parameters compensatory movement strategies were observed.

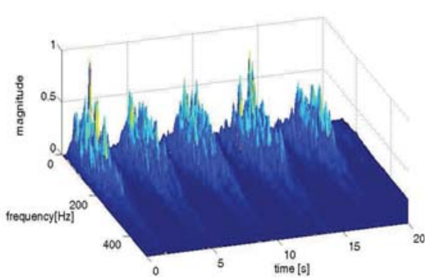

Figure 1: Time Frequency Distibution for vastus lateralis while repetitive lifting of a weight (40 kg)

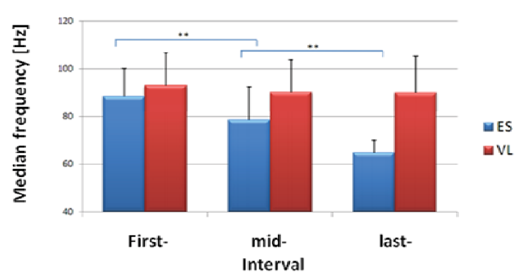

Figure 2: Median frequency of the EMG-signals for VL and ES in different stages of the lifting test (PILE)

ELECTROMOTIVE FORCE: METHODS TO UNDERSTAND HUMAN MOVEMENT

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The history of electrophysiology dates back to the famous work of Luigi Galvani, who first came with the notion of the relation between electricity and life, “animal electricity” (1791). The relation he found between electricity and mechanical muscle activity still is the overarching theme of the ISEK society. But only in the 20-th century electrophysiology became practically useful through the development of electronic equipment suited to measure low voltages with a high temporal resolution.

Currently, high-quality equipment allows the patch-clamp study of single ion-channels, the smallest functional electrophysiological entities. Despite this progress, applied electrophysiological signals mostly express “mass activity” of the nervous and the neuromuscular system. That is firstly because of the need for non-invasive observations, but secondly also because of the intrinsic fact that voluntary central and peripheral bioelectric activity virtually always is of a “mass” character. This applies similarly to the result of involuntary nervous tissue activation by electrical and magnetic stimulation.

A general challenge in biomedical signal processing will thus be to decompose compound signals into (neuro)physiologically or clinically useful information. I will start by giving an impression of fundamental hurdles in the decomposition and interpretation of EMG and neurography signals and the many attempts made to overcome those obstacles. That these tasks are not straightforward is obvious from the strong engineering involvement in this research field. But diagnostics and therapy in neurological and neuromuscular diseases still require improved principles for recording and analysis. Examples will be shown that indicate the need for a detailed understanding of (patho)physiological and biophysical processes for improving and validating methods.

A basic requirement for signals related to movements is a high temporal resolution. Therefore studies of spinal circuits and cortico-muscular interactions are strongly dependent on electrophysiological measurements. Interrelating EMG signals and electrophysiological brain signals (EEG/MEG) is an important way to study normal and pathological control of human movement. It will be illustrated that insight in the generation of EMG signals and their proper analysis is important next to advanced EEG and MEG analysis.

Crucial in understanding scientific data, also in our discipline, is the availability of relevant models. During this lecture, it will become obvious that the discussed facts, problems and solutions need model based interpretations. They can be models at the level of single cells to understand membrane characteristics, and they can be dynamic models of the control of movement systems. Last but not least, we need volume conductor models expressing the relation between the single cell activity at the membrane level, via “mass” cell activation, to our global voltage recordings or global electric stimulation.

PAIN AND MOTOR CONTROL: FROM THE LABORATORY TO REHABILITATION

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Movement changes in pain. Despite the obvious nature of this statement there is little agreement regarding the underlying physiology and its relevance to rehabilitation. Changes in the motor system can occur at many levels of the nervous system and our group have investigated a number of these; from the control of groups of motoneurones (i.e. motor unit, the smallest functional unit of the motor system) during simple contractions, to changes in organisation of the motor cortex and coordination of muscle behaviour in complex tasks. At the motoneurone level new data do not support the notion of uniform inhibition and excitation of whole muscles that are predicted by the "pain adaptation" theory. Instead, our data point to changes in recruitment of motoneurones such that the force direction[1] and order of motoneurone recruitment[2] is modified. Both factors modify loading, joint protection and the capacity to escape from threat. At the cortex, although changes in primary somatosensory regions are well known, recent work has highlighted plastic changes in the motor cortex in chronic low back pain[3] and in animals following intervertebral disc lesions[4]. These changes are associated with changes in behaviour of trunk muscles. Biomechanical studies provide direct evidence that new strategies adopted during pain and injury tend to increase protection of injured or painful parts[5]. Although this has the potential for short-term benefit for the system to prevent further pain and injury, there is likely to be mechanical consequences that are potentially problematic in the long term. Rehabilitation of these changes is linked to clinical improvement in controlled clinical trials[6]. Other work is testing underlying mechanisms for efficacy of clinical interventions. This work shows that; motor training leads to improvements in pain and disability, efficacy of these approaches is associated with improved motor performance, and improvements in motor performance are associated with recovery of plastic changes at the motor cortex[7]. In summary, these new data highlight an adaptation to pain, that is more complex that predicted by current models, but can be rehabilitated, thus contributing to better outcomes for those with pain.

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THE PLASTICITY IN NEUROMUSCULAR FUNCTION WITH TRAINING: IMPLICATIONS FOR ATHLETES, ELDERLY AND PATIENTS

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Strength training (resistance exercise) appears to be highly effective of inducing adaptive changes in nervous system function, in turn increasing maximal muscle force and power in vivo. This can be observed both in athletes and young and aging persons, including frail and very old individuals, and patients recovering from surgery or musculoskeletal injury.

The adaptation in neuromuscular function with training has been evaluated by use of muscle electromyography (EMG) measurements, including single motor unit recording and measurements of evoked spinal reflex responses (Hoffmann reflex, V-wave) and transcranial brain stimulation (TMS, TES). Also, interpolated muscle twitch recording has been used to assess the magnitude of central activation of skeletal muscle fibers, while peripheral nerve stimulation recently has been used to examine aspects of inter-muscular synergist inhibition.

The capacity for rapid force production (i.e. a high rate of force development, RFD = ΔForce/Δtime) in the initial contraction phase is vital to the trained athlete, while also important for elderly individuals to control postural balance etc. Parallel increases in RFD, muscle EMG amplitude and rate of EMG rise were observed in the initial contraction phase following strength training. Adaptation mechanisms include increased motorneuron firing frequency and an elevated incidence of doublet discharge firing of spinal motorneurones.

Evoked spinal responses (Hoffmann (H) reflex, V-wave) can be used to examine training induced changes in the spinal neural circuitry function at rest and during active muscle contraction. Elevated V-wave and H reflex amplitudes have been observed during maximal muscle contraction following strength training, which indicate an enhanced neural drive in descending corticospinal pathways, elevated motorneuron excitability, reduced presynaptic inhibition of Ia afferents and/or reduced postsynaptic motorneuron inhibition.

TMS recently has been used to assess training-induced changes in the transmission efficacy in descending motor pathways from the cerebral cortex to the muscle fibers including the spinal cord. Increased motor evoked potentials (MEPs) during submaximal muscle contraction have been reported following strength training by some (but not all) investigators, suggesting that corticospinal excitability may be increased by this type of training.

Collectively, the available experimental data demonstrate a substantial adaptive plasticity in human nervous system function with training, which appears to be equally beneficial for the elite athlete as well as in untrained young and elderly individuals recovering from muscle-tendon injury, hospitalization or sarcopenia.

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COMPARISON OF DENOISING TECHNIQUES FOR NEURAL RECORDINGS

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AIM: Intraneural recordings are of increasing importance due to the recent development of advanced neural interfaces. However, despite being more selective than extraneural recordings, they still suffer from high noise levels, e.g., in the case of longitudinal intrafascicular electrode (LIFE) recordings, the signal-to-noise ratio (SNR) is usually below 6 dB. This clearly calls for denoising techniques able to extract the relevant information for the identification of single unit action potentials. Therefore, in this study we compared state-of-the-art wavelet-based denoising techniques to assess their relative merits and performance in case of high noise levels.

METHODS: Most wavelet-based denoising techniques exploit the sparseness property of the transform, i.e. the fact that the signal part of the recording is distributed across few coefficients of the transformation whereas the noise influences all coefficients. The task is then to separate the signal from the noise in the transformed domain and this is usually performed by means of thresholding: either hard thresholding, where some coefficients are simply classified as noise and discarded, or soft-thresholding where a fixed value is subtracted from all coefficients. Different techniques have been developed in the literature to optimally choose the threshold value, either based on a frequentist approach, or on a bayesian approach minimizing the expected bayesian risk. A third approach, originally proposed by Rissanen [1], is based on the Minimum Description Length principle to classify the coefficients either as noise or signal based on the assumption that the “compressible” part of the coefficients represents the signal (i.e., assuming that noise is intrinsically more complex than the signal). We tested various wavelet based techniques on a set of synthetic intracortical signals. Gaussian white noise was added to the signals which were, in turn, transformed using 10 levels decomposition using a Daubechies D6 mother wavelet. The signals were generated by summing experimental intracortical action potentials in random time instants.

RESULTS: Figure (1) depicts the performance over different noise levels for the techniques compared. MDL soft denoising (called MDL-ABC in the original paper) outperformed the other techniques at almost all the noise levels, while the original MDL technique had good performance only for low noise levels.

CONCLUSION: The SNR of neural recordings can be increased substantially by wavelet denoising. However, the criterion used for threshold selection has a major impact on the performance.

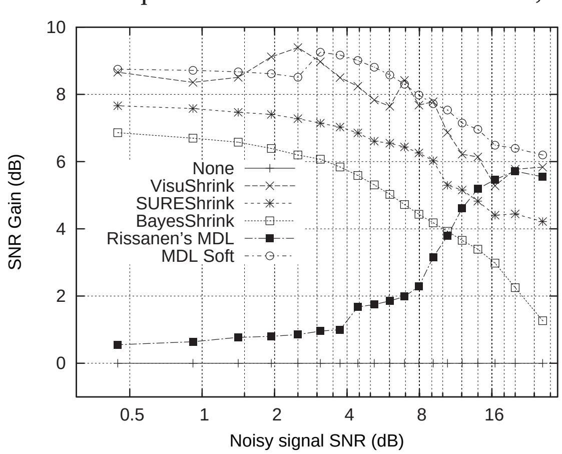

Figure 1: Denoising performance of the tested techniques under different noise levels (simulated signals, 1048576 samples, 24 kHz). For each technique the relative gain (with respect to no denoising) is shown for different noise levels.

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REDUCED FORCE STEADINESS IN WOMEN WITH NECK PAIN AND THE EFFECT OF SHORT TERM VIBRATION

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AIM: To compare neck force steadiness in women with neck pain and controls and the way this is influenced by short term vibration of the neck.
METHODS: This study includes two experiments. In the first experiment, 9 women with chronic neck pain and 9 controls performed 10-s isometric cervical flexion at 15 N. Intramuscular EMG was recorded bilaterally from the sternocleidomastoid muscle.
In the second experiment, 10 women with neck pain and 10 controls performed 10-s isometric cervical flexion contractions at 25 % of their maximal force before and after vibration to the neck (bursts of 50 Hz with duration 20, 40, 60 and 120s, with 60s of rest in between). During these contractions, surface EMG was detected from the sternocleidomastoid and splenius capitis muscles. In both experiments, force steadiness was characterized by the coefficient of variation (CoV) and the relative power in three frequency subbands (low: 0-3 Hz; middle: 4-6 Hz; high: 8-12 Hz) of the force signal. The discharge rate and inter-spike interval variability of motor units were assessed in Exp 1 and the average rectified value of the surface EMG was assessed in Exp 2.
RESULTS: Women with neck pain exhibited decreased force steadiness compared to control subjects (Exp 1: patients 3.9±1.3 %, controls 2.7±0.9 %, $P<0.05$; Exp 2: patients 3.4±1.2 %, controls 1.7±0.6 %, $P<0.001$) and this was associated with higher power in the low-frequency band (patients 56.7±9.2 %, controls 71.2±9.6 %, $P<0.01$). Following vibration, force steadiness increased (2.6±1.1 %, $P<0.05$) and the power in the low-frequency band of the force signal decreased (63.1±13.9 % $P<0.05$) in the patient group. These effects were not present in control subjects. The two groups did not exhibit differences in discharge rate and inter-spike interval variability of motor units (Exp 1) and in EMG amplitude (Exp2).
CONCLUSION: In conclusion, women with neck pain have reduced force steadiness. Since neural input from the Ia afferent circuit contributes to force fluctuations at low frequencies (≤ 4 Hz), this impairment in steadiness is likely due to alterations in Ia afferent input. Short term vibration, which elicits Ia afferent input, increases force steadiness in patients with neck pain.

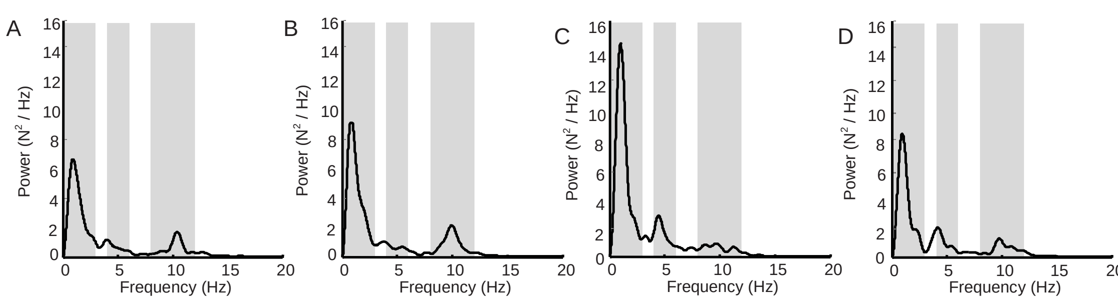

Figure: Power spectrum of the force signal from a representative control subject pre (A) and post vibration (B) and from a representative subject with neck pain pre (C) and post vibration (D). The panels present the three frequency bands of interest (0 to 3, 3 to 6, and 8 to 12 Hz).

PAIN-INDUCED CHANGES IN TRUNK MUSCLE ACTIVATION DURING UNANTICIPATED POSTURAL PERTURBATIONS

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AIM: To determine if acute experimental low back pain (LBP) alters trunk muscle activity during unanticipated postural perturbations. Unlike previous studies, this study involved entire body perturbations.

METHODS: Surface EMG signals were recorded from the erector spinae (ES) and external oblique (EO) muscles bilaterally from 10 healthy subjects (23±1.0 yrs) during unanticipated postural perturbations at baseline, immediately following injection of isotonic saline (control condition) and immediately following injection of hypertonic saline (experimental muscle pain) into the right ES at the level of the second lumbar vertebra. In each condition, subjects were asked to stand on a moveable platform in a relaxed posture. The platform was set to perform four perturbations: 8 cm forward slide, 8 cm backward slide, 10° posterior tilt, and 10° anterior tilt. Each perturbation was repeated eight times for a total of 32 perturbations per condition. The 32 perturbations were randomized and occurred with random time intervals of 7 – 20 s, so that neither the type nor the time of the perturbation could be predicted by the subjects. The onset of muscle activity and the EMG amplitude (averaged over 300 ms following the onset of the perturbation) were determined for the four perturbations in each trial. Subjective pain intensity was verbally conveyed to the investigator and recorded every 20 s using a numerical rating scale (0-10).

RESULTS: The peak pain intensity following injection of hypertonic saline was 4.0±0.5. The onset time of the ES and EO activity was delayed following injection of hypertonic saline for the forward and backward slide perturbations ($P < 0.05$, Fig 1A). Furthermore, EMG amplitude of the ES and EO was reduced for all perturbations following injection of hypertonic saline ($P < 0.05$, Fig 1B).

CONCLUSION: Acute unilateral experimental low back pain modulates motor control of the trunk bilaterally during unanticipated whole body postural perturbations. These results suggest that acute low back pain may compromise the stability of the spine, which in turn may be relevant for the recurrence of back pain following a first episode of pain.

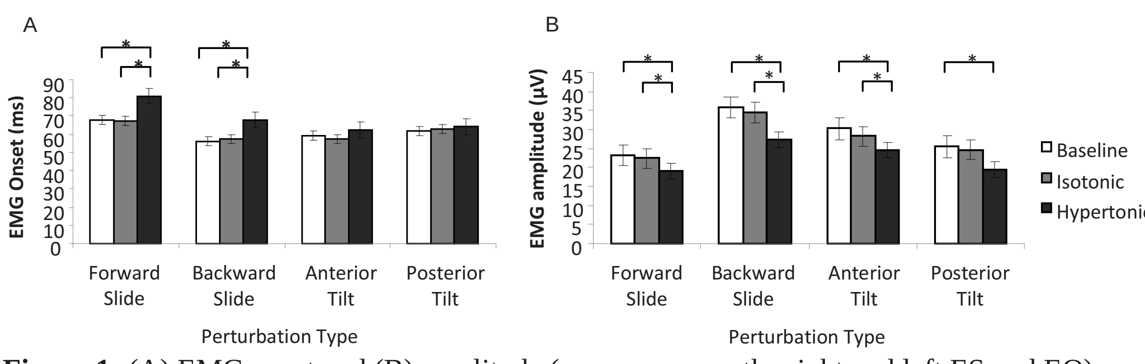

Figure 1: (A) EMG onset and (B) amplitude (average across the right and left ES and EO) during whole body perturbations performed at baseline, immediately following injection of isotonic saline and immediately following injection of hypertonic saline (experimental muscle pain) into the right ES. Asterisk indicates significant difference ($P<0.05$).

ASSOCIATION BETWEEN NECK MUSCLE CO-ACTIVATION, PAIN, AND STRENGTH IN WOMEN WITH NECK PAIN

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AIM: To investigate the relation between the amount of coactivation of the neck muscles, neck strength and perceived pain and disability in women with persistent neck pain.
METHODS: Thirteen women with chronic neck pain (duration of pain, mean ± SD: 7.1 ± 6.1 yrs) and 10 age- and gender-matched controls performed 1) two maximal voluntary contractions (MVC) in flexion, extension and left and right lateral flexion, 2) ramped contractions from 0% to 50% MVC over 3 s in both flexion and extension, and 3) circular contractions in the horizontal plane at 15 N and 30 N force with continuous change in force direction in the range 0-360º. Surface EMG was recorded bilaterally from the sternocleidomastoid (SCM) and splenius capitis (SC) muscles. The EMG average rectified value (ARV) was computed over five intervals of 250-ms duration, during which the average force level was 10-50% MVC (10% MVC increments). Tuning curves of surface EMG ARV were computed from the circular contractions. The mean point of the ARV curves defined a directional vector, whose strength, expressed as a percent of the mean ARV during the entire task, defined the directional specificity of the muscle activity.
RESULTS: The patients' average score of perceived disability (Neck Disability Index; 0-50) was 21.6 ± 8.4 and their average pain intensity rated on a visual analogue scale (0-10) was 5.1 ± 1.8. The maximum voluntary neck strength was lower in the patient group for all force directions ($P < 0.05$). For the ramped neck flexion contraction, higher values of ARV were observed for the SC (antagonist) in the patient group ($P < 0.05$). Similarly, greater values of ARV were observed for the SCM during the ramped extension contractions in the patient group. The patients displayed reduced values of directional specificity in the surface EMG of the SCM and SC bilaterally for both the 15 N and 30 N circular contractions ($P < 0.05$). The ARV of SC during cervical flexion of the patients was positively correlated with the reported pain ($R^2 = 0.35$, $P < 0.05$) and perceived disability ($R^2 = 0.53$, $P < 0.01$). Furthermore, an inverse correlation between the amount of activation of SC during cervical flexion and neck strength was evident ($R^2 = 0.54$, $P < 0.01$).
CONCLUSION: These observations indicate a relation between alterations in neuromuscular control of the cervical spine in patients with neck pain and functional consequences, including impaired motor performance and increased levels of perceived disability.
ACKNOWLEDGEMENT: Supported by the Danish Medical Research Council, Kiropraktorfonden, Denmark and Østifterne, Denmark.

EFFECTS OF ECCENTRIC EXERCISE ON FORCE STEADINESS AND VOLUNTARY ACTIVATION OF THE KNEE EXTENSORS

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AIM: The purpose of this study was to investigate the effects of eccentric exercise of the knee extensors on force steadiness and neural drive to the vasti muscles during submaximal isometric contractions.
METHODS: Ten healthy subjects (age, mean ± SD, 24.9 ± 3.2 yrs) participated in the study. The subjects performed maximum voluntary contractions (MVC) of the knee extensors followed by isometric contractions at 2.5, 5, 10, 15, 20 and 30% MVC at baseline, immediately after and 24h after eccentric exercise of the quadriceps. During each contraction, force and surface EMG of the vastus medialis (VM), vastus lateralis (VL), biceps femoris (BF), and semitendinous (ST) muscles were recorded concurrently. Force steadiness was characterized by the coefficient of variation (CoV; SD divided by mean, %) of the force signal.
RESULTS: The MVC force decreased from baseline (665.5 ± 256.9 N) to 24 h post exercise (596.2 ± 123.2 N, $P<0.001$) and from immediately post exercise (636.5 ± 131.8 N) to 24h post exercise ($P<0.05$). The CoV during the submaximal isometric contractions was greater immediately after eccentric exercise (up to 66% higher than baseline values, $P<0.001$; Fig 1A) and remained higher 24h post exercise (up to 50% higher than baseline values, $P<0.01$). Reduced force steadiness was accompanied by increased EMG amplitude of the vasti muscles ($P<0.01$) (Fig 1B) whereas the EMG amplitude of the BF and ST did not change across conditions ($P>0.05$).
CONCLUSION: Eccentric exercise of the quadriceps impairs knee extension force steadiness and is associated with reduced activation of the vasti muscles both immediately after and 24h after exercise. This reduction in force steadiness is not due to increased antagonist activity.
ACKNOWLEDGEMENT: Fundação para a Ciência e a Tecnologia (FCT) of Portugal.

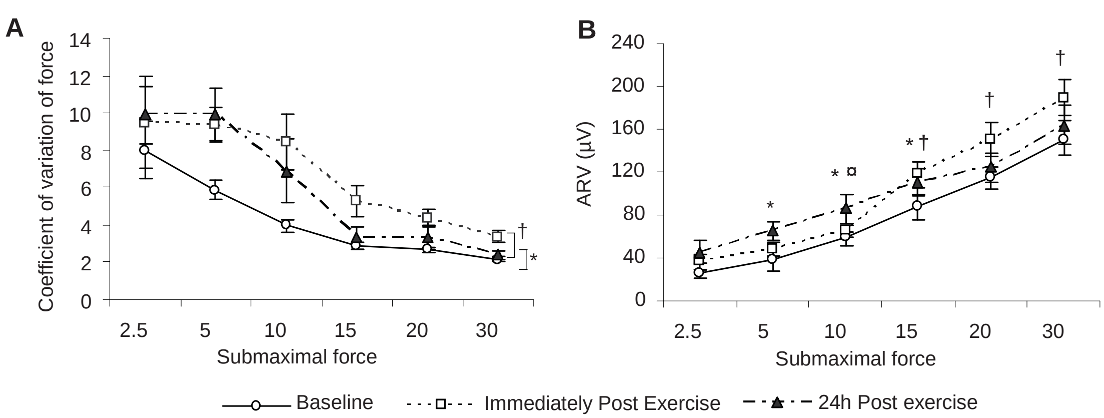

Figure 1: Coefficient of variation of force (A) and EMG amplitude of the vasti muscles (B) during isometric contractions at 2.5, 5, 10, 15, 20 and 30% MVC, before, immediately post and 24h after eccentric exercise of the quadriceps. †: $P<0.05$ from baseline to immediately post exercise; *: $P<0.05$ from baseline to 24h post exercise; ¤: $P<0.05$ from immediately post to 24h post exercise.

THE EFFECT OF SHORT-TERM ENDURANCE AND STRENGTH TRAINING ON MOTOR UNIT CONDUCTION VELOCITY

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AIM: The aim of this study was to investigate the effect of strength and endurance training on the conduction velocity of vastus medialis obliquus and lateralis single motor units during voluntary sustained knee extensions.
METHODS: Seventeen sedentary healthy men (age, mean ± SD, 26.3 ± 3.9 yr) were randomly assigned to one of 2 groups: strength training (ST, n= 8) or endurance training (ET, n= 9). Conventional endurance and strength training was performed three days per week, over a period of 6 weeks. Motor unit conduction velocity (MUCV), maximum voluntary force (MVC) and time-to-task failure at 30% MVC of the knee extensors were measured before and immediately following training. To assess MUCV, multi-channel surface and intramuscular EMG signals were concurrently recorded from the vastus medialis obliquus (VMO) and vastus lateralis (VL) muscles during 60-s isometric knee extensions at 10% and 30% of MVC.
RESULTS: After 6 weeks of training, MVC increased in the ST group (16.7 ± 7.4 %; $P < 0.05$) whereas time to task failure was prolonged in the ET group (33.3 ± 14.2 %; $P < 0.05$). Both training programs induced an increase in motor unit conduction velocity at both 10% and 30% MVC (Fig. 1A; $P < 0.01$). Furthermore after both training programs, the reduction in MUCV over time during the sustained contractions occurred at slower rates compared to baseline (Fig. 1B; $P < 0.01$).
CONCLUSION: These results indicate that short-term endurance and strength training induce similar alterations of the electrophysiological membrane properties of the muscle fiber and in their changes during sustained contractions.
ACKNOWLEDGEMENT: Grant SFRH/BD/31796/2006 from Fundação para a Ciência e a Tecnologia (FCT) of Portugal.

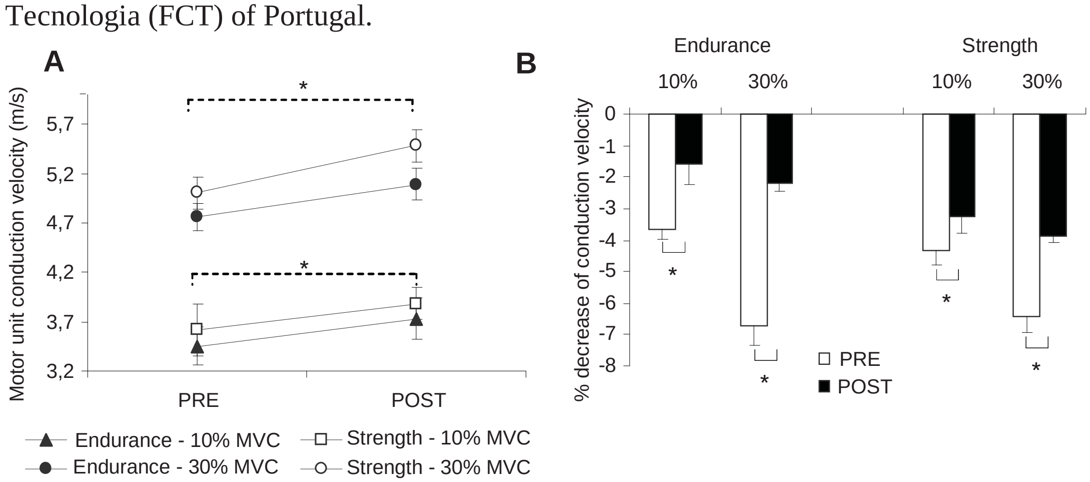

Figure 1: Initial values of motor unit conduction velocity **(A)** and percent decrease in motor unit conduction velocity **(B)** in the vasti muscles (average of VMO and VL) during sustained knee extensions at 10% and 30% of MVC in the endurance and strength group. ** $P < 0.01$.

RAPID CHANGES IN CORTICAL EXCITABILITY ASSOCIATED WITH NOVEL MOTOR LEARNING OF A HAND TASK

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AIM: The aim of this study was to determine the degree of changes in cortical excitability induced by novel skill training of a hand muscle and to concurrently investigate motor unit behaviour following training.
METHODS: Surface and intramuscular electromyography (EMG) were recorded from the right abductor digiti minimi (ADM) muscle in 12 healthy subjects. Subjects performed maximum voluntary contractions (MVC) of fifth finger abduction at the beginning and end of the session. Cortical excitability was assessed using TMS. Motor evoked potentials (MEP) were elicited in the right ADM at 1.4 and 1.8% MEP threshold before and after a baseline condition and again after a repetitive-training regime. The baseline condition consisted of a 10-min rest period during which subjects maintained a stable position of their hand and arm. After the TMS-MEP baseline measures and immediately before and after training, surface and intramuscular EMG were acquired during isometric fifth finger abduction sustained for 30 s at 10 and 20% MVC. The training protocol consisted of 65 isometric contractions (3-s each) at 10% MVC with 10-s rest intervals. During the isometric contractions the subject maintained a cursor within a pre-determined target force level (10 ± 2.5% or 20 ± 2.5% MVC) by voluntarily abduction of the fifth finger. A performance index was calculated as the percent of the total contraction time during which the subject maintained the cursor within the target level.
RESULTS: There was no difference in maximum force output between pre- and post-training MVC measures, indicating the absence of fatigue. The peak-to-peak amplitude of the surface TMS-MEP increased following training (1.4 % TMS: 46.0 ± 13.1 % increase; 1.8 % TMS: 51.2 ± 16.3 %) when compared to baseline ($P<0.05$). Similar results were found for the intramuscular TMS-MEPs ($P<0.05$). The performance index increased for the contractions at 10 % (11.2 ± 3.1%) and 20% MVC (14.3 ± 4.2%) following training ($P < 0.001$), however there were no associated changes in the surface EMG amplitude ($P=0.17$). Furthermore, performance increased during the training protocol from 74.6 ± 4.5 % (trials 1-3) to 85.5 ± 3.7 % (trials 63-65) ($P<0.05$).
CONCLUSIONS: Rapid changes in cortical excitability can occur after short periods of novel isometric training of the hand muscles where visual feedback of performance is provided. These rapid changes in cortical excitability are associated with improvements in motor skill behaviour and may initiate the changes in motor unit behaviour that are known to occur with long-term motor training.

SYMPATHETIC ACTIVATION IMPAIRS PROPRIOCEPTIVE ACUITY OF THE NECK

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AIM: Neck pain is associated with impaired proprioception, characterised by a reduced ability to accurately reposition the head following neck movement. Alterations in proprioception may reflect abnormal spindle afferent discharge either due to activation of chemo- and nociceptive sensory afferents, direct trauma to cervical structures, or increased sympathetic drive. Specifically, the sympathetic nervous system modulates the proprioceptive activity from muscle spindle afferents and may contribute towards impaired proprioception in patients with neck pain. This study investigates the effect of sympathetic activation on proprioceptive acuity of the neck in healthy individuals. Physiological sympathetic activation was elicited by the cold pressor test (CPT) which is known to elicit secretion of adrenaline.

METHODS: 10 healthy subjects (7 males, age 23.1 ± 4.9 yr) volunteered for a single session experiment which consisted of baseline, control (right hand immersed in water at 32–35°C), CPT (right hand immersed in water at 4°C), and recovery conditions. In each condition, the subject's ability to relocate their natural head and neck posture was tested following 10 randomized (5 left and 5 right) active cervical rotations whilst blindfolded. Subjects were instructed to remember their natural head posture prior to each head rotation, rotate their head to a predetermined angular displacement, and then return to their natural head posture. In each condition, movement of the head was measured with a 3-Space Fastrak (Polhemus) device and the absolute value of the repositioning error in addition to maximum angular velocity and movement time (outwards and inwards) for the left and right cervical rotations were determined. Surface electromyography (EMG) activity was recorded from the left and right sternocleidomastoid (SCM) and splenius capitis (SC) muscles and averaged over 10° angular displacement intervals (range 0 – 50°) for the left and right cervical rotations. Systolic and diastolic blood pressure (BP) and heart rate (HR) were recorded immediately before, during, and after each condition. Pain intensity was recorded on a numerical rating scale (NRS; 0-10) every 30 s.

RESULTS: The mean pain intensity throughout the CPT trial was 3.6 ± 0.3. Both systolic and diastolic BP were elevated in the CPT (134.7 ± 5.8 and 91.8 ± 3.6 mmHg) when compared to the baseline (114.7 ± 3.9 and 74.5 ± 4.2 mmHg), control (113.7 ± 3.5 and 75.6 ± 2.9 mmHg), and recovery (116.7 ± 4.1 and 79.2 ± 3.2 mmHg) conditions (ANOVA: $P < 0.001$; post-hoc: $P < 0.001$). The mean repositioning error was greater in the CPT (3.23 ± 0.20°) when compared to the baseline (2.15 ± 0.23°), control (2.47 ± 0.31°) and recovery (2.63 ± 0.24°) conditions (ANOVA: $P < 0.01$; post-hoc: $P < 0.05$). Maximum angular velocity and movement time (inwards and outwards) for the left and right rotations were similar across conditions. The activity of the SCM was increased during the CPT but only at 40-50° of active contralateral rotation ($P < 0.05$). The CPT also resulted in increased activity for the left SC in the interval of 40-50° of both left and right cervical rotation ($P < 0.05$).

CONCLUSION: Activation of the sympathetic nervous system in healthy individuals impairs proprioception of the neck and increases the activation of the superficial neck muscles during active cervical rotation. These observations may partly explain disturbances in relocation accuracy and increased muscle coactivation observed in patients with neck pain.

SURFACE EMG CLASSIFICATION DURING DYNAMIC CONTRACTIONS FOR MULTIFUNCTION TRANSRADIAL PROSTHESES

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AIM: The control of multi-function prostheses with surface EMG requires robust classification schemes during dynamic contractions. Therefore, this work investigates the impact of the training data set on the classification accuracy of several pattern recognition algorithms during dynamic contractions.

METHODS: 8 motions of the hand and wrist (wrist flexion, wrist extension, forearm pronation, forearm supination, thumb close, 4 finger close, making a fist, fingers spread open) were performed starting and ending in the rest position. In each contraction, two segments of dynamic portion (3-s at each end) and one segment of static portion (4-s in the middle) were extracted from the recorded EMG signals (6 bipolar recordings around the forearm at equal distances from each other, one third distal from the elbow joint). Classification of the tasks was performed over a sliding window with various combinations of feature extraction methods (time domain and autoregressive coefficients, wavelet transform) and classifiers (linear discriminant analysis, support vector machines in one versus rest mode and one versus one mode). An automatic thresholding technique was used to detect the onset of the movement (Solnik et al. 2008) and minimize the probability of wrong classification of active classes to rest class. Different portions of each contraction (only the static portions, the static portions plus 1s at each end, the static portions plus 2s at each end, the entire contraction, and threshold-based portions) were used as training set to study the impact of the choice of the training data.

RESULTS: The performance of all the algorithms tested substantially improved (range of improvement 5.1% to 6.9%) by optimizing the choice of the training set. When using wavelet-based feature set and an SVM classifier, the accuracy was 93.5% on dynamic contractions when the training set included the dynamic portions, whereas it was only 87.4% when the training set included only static portions. A simpler pattern recognition scheme based on time domain features and linear discriminant analysis classifier also achieved high accuracy (up to 91.9%) on dynamic contractions when the training set included dynamic signal portions (87.4% when the training set included only static portions).

CONCLUSION: The choice of the training set is a key factor for myocontrol strategies using the pattern recognition approach in dynamic anisotropic conditions. Moreover, rather simple approaches for classification and time-domain features provide results comparable to more complex methods. Finally, the current algorithms, combined with an activation threshold, achieve high accuracy in surface EMG classification during dynamic contractions for a multi-function hand and wrist prosthesis.

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UNSUPERVISED WAVELET OPTIMIZATION FOR DETECTION AND CLUSTERING OF INTRA-CORTICAL ACTION POTENTIALS

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AIM: In this study we developed an unsupervised method for denoising, detecting, and clustering intracortical neuronal activity.
METHODS: Simulated signals were generated from spike templates of an experimental dataset [1]. The signals were transformed in the time-scale domain by using the parameterized stationary wavelet transform (SWT) over 5 scales. The wavelet coefficients over the 3 scales with maximum energy were combined to form a manifestation variable to which a threshold was applied for detection. After spike detection, principal component analysis was applied to the wavelet coefficients of each detected spike to obtain features for the subsequent classification. The features were clustered with an unsupervised hierarchical clustering. The optimal mother wavelet in the parameterized SWT was chosen with a criterion that minimized the spread of features within the classes and maximized the distance between classes. The proposed method was tested in 3 sets of simulated signals. The action potentials were distributed randomly in each signal. Each set of signals was analyzed with 3 levels of added white Gaussian noise, corresponding to a standard deviation of 0.25, 0.3, and 0.35 (average peak of the spikes: 0.7). Twenty noise realizations were added for each noise level. The results are presented in terms of the detection error rate as summation of false positives and false negatives divided by total number of spikes. The optimal wavelet selection (OWS) method proposed was compared with an amplitude threshold detection (TR) method [1].
RESULTS: Figure 1 shows an example of manifestation variable for detection. Table 1 reports the results for the 3 signal sets and the two methods tested. For noise level corresponding to 0.25 standard deviation, the proposed method reduced the detection error rate by >10% with respect to the TR approach. For noise level of 0.35 the improvement was even greater.
CONCLUSION: A method for detection and clustering of intracortical action potentials has been proposed and tested on simulated signals. The method showed a substantial improvement in detection accuracy with respect to amplitude threshold approaches.

Table 1: Detection error rates (%) for the OWS and TR algorithms.

Noise level	0.25		0.30		0.35	
Method	TR	OWS	TR	OWS	TR	OWS
Signal 1	11.3 ± 2.1	1.4 ± 1.1	34.5 ± 4.5	4.8 ± 2.0	57.3 ± 3.5	10.0 ± 2.9
Signal 2	15.3 ± 2.6	1.1 ± 1.0	43.9 ± 5.4	8.2 ± 4.7	67.8 ± 5.1	20.0 ± 4.8
Signal 3	12.0 ± 3.0	1.9 ± 1.0	36.8 ± 5.0	6.8 ± 2.3	60.6 ± 4.8	15.7 ± 2.9

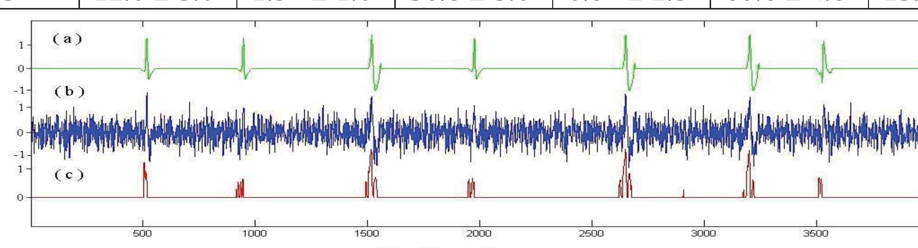

Figure 1: (a) Simulated signal without noise. (b) Simulated signal with noise (0.35 standard deviation). (c) Proposed combination of wavelet coefficients (manifestation variable).

[1] Quiroga et al. Neural Comput. 2004 Aug;16(8):1661-87.

EFFECT OF ABSTRACT FEEDBACK FOLLOWING USE OF BRAIN COMPUTER INTERFACE FOR UPPER LIMB REHABILITATION

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AIM: EEG-based brain–computer interface (BCI) technologies can be used to control an external device, such as functional electrical stimulation (FES) or a limb orthosis. By re-establishing some independence, BCI technologies can substantially improve the lives of people with devastating neurological disorders, such as advanced amyotrophic lateral sclerosis. BCI technology might also restore more effective motor control in people affected by stroke or other traumatic brain disorders by inducing brain plasticity. The aim of this study is to demonstrate that the use of a BCI induces plastic changes in the motor cortex.
METHODS: Two healthy subjects (31-33 years) participated in this preliminary investigation. They were trained to two motor imaginary tasks, slow and fast right arm flexion, using an online BCI system that classifies two speeds of imagined movements from features of the movement related cortical potentials (MRCPs). After performance of each imagined task, the subjects were presented with abstract feedback (text of different colors) on the result of the online classification. Features from 8 EEG channels were extracted using the discrete wavelet packet transform. These features were classified using support vector machine. The training session for the classifier consisted of 20 trials for each task. The test session was divided into six sub-sessions, each consisting of 10 trials per task. Tasks were presented to the subject in a random order during both the training and test sessions. The cues for the tasks were presented visually in form of videos of a person performing the movement at the desired speed. This type of visual cues activates the mirror neuron system, which is also activated during actual movements. The changes in cortical excitability were measured from the recruitment curves (RC) elicited by transcranial magnetic stimulation (TMS) applied before and immediately after the test session. The RC was determined from the amplitude of the motor evoked potentials (MEPs) at 100% (L1), 110% (L2), 120% (L3), and 130% (L4) of the resting threshold for each subject.
RESULTS: The online classification had average accuracy of 65% and 63% in the two subjects. The RC for the MEPs indicated an increase in MEP amplitude of 9.8% and 103.0% in the two subjects, for intensities close to the threshold level (L1 and L2, respectively), whereas there were negligible changes (1.0 % and 1.1%) for the intensity level L3, and a decrease of 13.2% and 5.8% at L4.
CONCLUSION: These preliminary results show that cortical excitability may change following the use of an online BCI system with feedback. This result is the basis for the application of BCI to promote cortical plastic changes, which may facilitate the rehabilitation of motor functions. These preliminary results should however be substantiated by a larger subject sample.

COHERENCE BETWEEN CORTICAL OSCILLATIONS AND MOTOR UNIT SPIKE TRAINS

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AIM: The EEG signal recorded from the primary motor cortex is coherent with the surface EMG signal detected over the contralateral muscles. The coherence between these two signals presumably arises from the effective transmission of cortical oscillations to spinal motoneurons. However, corticomuscular coherence has never been shown directly from the spike trains of motor units. In this study, we used a computational model and an experimental approach to demonstrate the presence of coherence between the cortical input to motoneurons and the sum of the spike trains of a relatively small proportion of active motor units.
METHODS: The simulations were based on a model of populations of motoneurons that received common and independent inputs. A model of volume conductor and surface EMG generation was used to simulate the EMG signals. The motoneuron model was based on that described by Cisi & Kohn [1]. The input to the motoneuron pool was divided in common components (cortical and spinal) and independent components (membrane noise). The cortical input was modelled as a band-limited (15-35 Hz) white Gaussian noise to simulate the cortical oscillations that are usually found experimentally. The spinal input represented the input that originates from interneurons and muscle afferents and was simulated as band-limited (0 – 100 Hz) white Gaussian noise. The membrane noise was simulated as an independent signal for each motoneuron. The experiments were conducted on 7 healthy men (age: 26.6 ± 3.4 yrs). EEG was recorded concurrently with intramuscular and surface EMG during 5 isometric contractions of the abductor digiti minimi muscle at 5% of the maximal force sustained for 1 min, with 5 min rest in between. Coherence was estimated [2] between the EEG and the EMG and between the EEG and the sum of spike trains of the identified motor units.
RESULTS: The coherence between the simulated cortical input and the superimposition of the spike trains of the active motoneurons was computed for increasing number of motor units. When only one motoneuron was used for this calculation, the peak coherence was 0.07 whereas the coherence level increased to 0.13 when 5 motor units were used, to 0.14 with 10 motor units, to 0.15 with 50 motor units, and to 0.17 when all active units (225 active motor units) were included in the calculation. From the experimental data, the coherence spectra had peak frequency of 20.1 ± 3.4 Hz (peak coherence value: 5.4 ± 1.3; z-transformed values) with the calculation with the cumulative spike train, and 17.3 ± 3.7 Hz (5.1 ± 1.3) with the calculation using the rectified EMG (not significantly different). When using only 50% of the experimentally identified motor units, the estimation of the coherence peak value was 78.3 ± 12.6 % of the value obtained with the entire pool of detected units. Therefore, the simulations and experimental data showed that sampling relatively few motor units is sufficient to accurately identify the corticospinal drive.
CONCLUSION: The corticospinal input to the motoneurons can effectively be sampled by a small percentage of the active motor units.
ACKNOWLEDGEMENT: Supported by the EU Project TREMOR (Contract # 224051) (DF).
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LOW FREQUENCY OSCILLATIONS OF MOTOR UNIT SPIKE TRAINS DETERMINE DECREASED FORCE STEADINESS WITH EXPERIMENTAL MUSCLE PAIN

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AIM: The neural control of muscles is altered by muscle pain. For example, pain determines a decrease in motor unit discharge rates during static contractions. In this study we investigated the influence of pain on the accuracy of task execution and motor unit discharge rates during low-force isometric contractions of the abductor digiti minimi muscle.
METHODS: Muscle pain was experimentally induced by infusion of sterile hypertonic saline (5.8%; one 0.5-ml bolus) into the mid portion of the abductor digiti minimi muscle of 11 healthy subjects (age, mean ± SD: 24.3 ± 5.6 yrs). Intramuscular EMG signals were recorded from the abductor digiti minimi muscle with two pairs of wire electrodes during 4 isometric contractions of 60-s duration at 10% of the maximal force, performed before (baseline), immediately after the injection of hypertonic saline (pain) or isotonic saline (control), and 15 min after the injection. Each 60-s isometric contraction was preceded by 2 linearly increasing force contractions from 0% to 10% of the maximal force of 3-s duration. Individual motor unit action potentials were identified from the intramuscular EMG signals with a decomposition algorithm. Low-frequency oscillations of motor unit spike trains were analyzed by the first principal component of the low-pass filtered spike trains (first common component, FCC) [1]. The strength of short-term synchronization and common drive were also computed from the motor unit spike trains. Force steadiness was quantified as the coefficient of variation (CoV) of the force signal.
RESULTS: None of the investigated variables were different among the baseline, control and post-pain conditions, thus results are reported for the baseline and pain condition only. Pain decreased the accuracy of task performance (CoV for force: baseline, 2.8±1.8 %, pain, 3.9±1.8%, $P < 0.05$). Motor unit discharge rates decreased with pain (11.6±2.3 pulses per second, pps, vs 10.8±2.1 pps, $P < 0.05$), as previously reported. However, the motor unit recruitment thresholds (2.0±1.3 %MVC vs 2.2±1.4 %MVC), the inter-spike interval variability (18.4±4.9 % vs 20.1±5.4 %), the strength of motor unit short-term synchronization (common input strength, CIS, 1.1±0.5 vs 0.9±0.3), and the strength of common drive (0.47±0.08 vs 0.46±0.06) did not change across conditions. The FCC was correlated with force in both the baseline ($R = 0.45 \pm 0.07$, $P < 0.05$) and painful conditions ($R = 0.44 \pm 0.06$, $P < 0.05$). Moreover, the CoV of FCC increased in the painful condition (5.6±1.3% vs 7.8±2.6, $P < 0.05$).
CONCLUSION: Muscle pain decreased force steadiness in an accurate isometric task of the abductor digiti minimi muscle. The impaired accuracy was determined by an increase in the variability of the low-frequency oscillations of motor unit spike trains. Since these oscillations are mainly determined by descending control signals [1], pain impaired supraspinal control.

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SIMULTANEOUS AND PROPORTIONAL ESTIMATION OF MULTIPLE DEGREES OF FREEDOM IN HAND KINEMATICS FROM THE SURFACE EMG

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AIM: To estimate wrist kinematics from surface EMG signals for the proportional and simultaneous control of multiple degrees of freedom (DOF).
METHODS: Six subjects were instructed to perform a series of mirrored bilateral dynamic wrist contractions. The protocol included six single-DOF movements (wrist flexion and extension, radial and ulnar deviation, forearm pronation and supination) and eight combined movements (wrist flexion and extension, radial and ulnar deviation while the forearm was pronated or supinated). Five trials of one repetition of the aforementioned movements were performed. Surface EMG signals were recorded from muscles of the right forearm using two semi-disposable adhesive grids of 32 electrodes. The kinematics of both limbs was concurrently recorded during the bilateral movements with a motion analysis system. EMG signals were full-wave rectified and low-pass filtered (16 Hz), and synchronized with the kinematics signals at a common sampling rate of 64 Hz. Six multi-layer perceptron (MLP) neural networks (each with 1 hidden layer, 6 neurons) were used to learn the association between the EMG signal envelopes and the flexion/extension, radial/ulnar deviation, pronation/supination angular displacements of the ipsi- and contra-lateral hand. Performance was evaluated in terms of coefficient of determination (the percent variability in the actual angular values explained by the predicted values). A five-fold cross validation procedure was employed, where 4 out of the 5 trials were used for training/validation, while the fifth one was used to test the behavior of the MLP in presence of novel inputs.
RESULTS: Figure 1 shows an example of recorded and predicted kinematics. The average coefficient of determination between the true and the predicted angular displacement was 84.3 ± 6.7% (80.5 ± 4.5%) for flexion/extension, 72.5 ± 5.8% (65.3 ± 9.5%) for radial/ulnar deviation, 86.3 ± 2.2% (79.5 ± 5.3%) for pronation/supination for the ipsi-lateral (contra-lateral) hand.
CONCLUSION: Wrist movements involving simultaneous activation of multiple DOFs could be accurately predicted using separate MLPs for each DOF. This configuration allowed obtaining high performance even for movements involving pronation and supination of the forearm, which are poorly estimated by the current state-of-the-art methods (Jiang et al. 2009). Moreover, the performance was high for both the ipsilateral and contralateral limb.

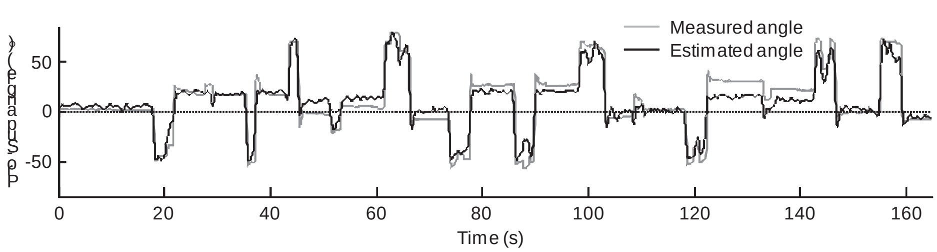

Figure 1: Representative example of the measured and the predicted angular displacement for pronation/supination.

Jiang N, Parker P, Englehart K, "Extracting Simultaneous and Proportional Neural Control Information for Multiple Degree of Freedom Prostheses from the Surface Electromyographic Signal", IEEE Trans. Biomed. Eng., Vol. 56, No. 4, April 2009, pp. 1070-1080

DETECTING TREMOR FROM THE SURFACE EMG

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AIM: Real-time detection of tremor is essential in any tremor suppression system. Tremor can be detected from the measure of the angular velocity of the limb using inertial sensors. However, this approach may not be optimal in some conditions since tremorous movements may be transferred across joints, making it difficult to identify which muscle is the source of tremor. Furthermore, the electromechanical delay hinders the possibility for real-time detection. For these reasons, this study presents two methods for multi-channel EMG-based tremor detection.

METHODS: The first method consists in the analysis of the spectral peak density (SPD) at the tremor frequency from the power spectrum of the EMG. The manifestation variable for the detector was twice the square root of the second order spectral moment of the signal in the band 4-14 Hz, which is the range of frequencies for tremor oscillations [1]. This variable was compared to a threshold and values smaller than the threshold indicated the presence of tremor.

The second method is based on the iterated Hilbert Transform (IHT), which provides a multicomponent AM-FM representation [2]. The IHT-based detector consists of the following steps: 1) the nonstationary filtering of the signals, 2) the Gini-Giannakis estimator in Hilbert Manifolds [3, 4, 5], 3) a maximum likelihood detection of the estimated projections. Under mild assumptions, this detector is optimal in the Neyman-Pearson sense.

RESULTS: Exhaustive experiments were performed and the effectiveness of the proposed approaches has been validated using experimental and simulated data. The detection accuracy of the second method was greater than the first because of the non-stationary filtering provided by IHT and the best detection under the fixed rank correction provided by the optimal detector in the Hilbert Manifold.

CONCLUSION: Two approaches for tremor detection from the surface EMG were developed, based on stationary and non-stationary filtering of the EMG signal. The IHT-based method seemed to be the best detector of the two proposed.

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MULTI-SCALE MODELING OF PATHOLOGICAL TREMOR

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AIM: Many different types of pathological tremor exist with a wide range of frequencies and amplitudes. Therefore, it is difficult to extract general information on the characteristics of limb movement and EMG activity in tremor without having a large number of patients, which is not always available. In this study, a novel multi-scale approach to computational modeling of pathological tremor is presented.
METHODS: The model combines a neuromuscular model of single motor unit activity and force production with biomechanical properties and a model for generation of surface EMG. Two similar antagonistic muscles were implemented acting on a limb moving in one dimension. Tremor was imposed to the neural input of both muscles as band-pass filtered white noise, in opposite phases for each muscle.
RESULTS: Frequency and amplitude of tremor as well as the angular trajectory of the limb can be varied in the model. Figure 1 depicts angle, surface EMG and the power spectrum of the surface EMG from a representative simulation of tremor during a 7-degree flexion. The characteristics of the EMG and the movement of the limb corresponded well to those observed experimentally over a wide range of conditions, and the single motor unit activity exhibited similar trends as those reported in the literature.
CONCLUSION: The model provides a unique tool for investigating and deriving information about different types of pathological tremor.

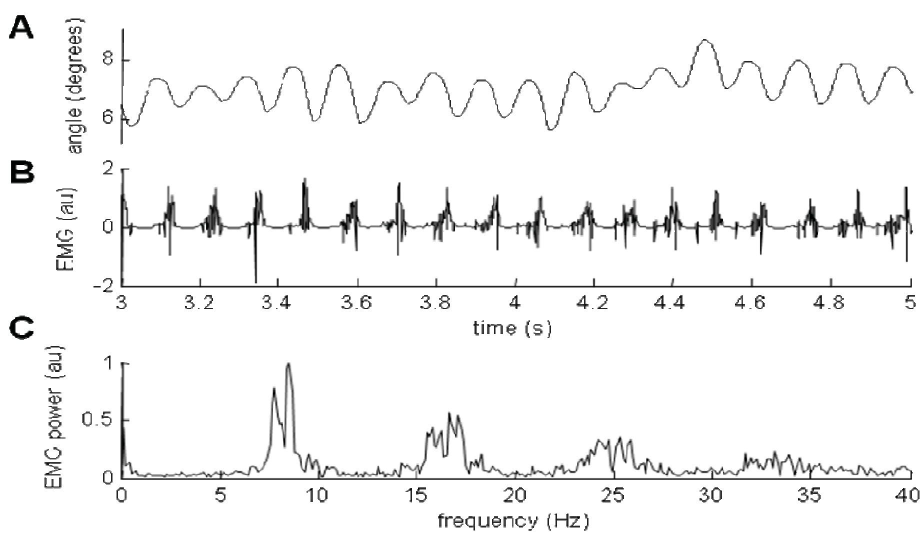

Figure 1: Angle (A), EMG (B) and the power spectrum of the EMG (C) during 2 s of a simulated 7-degree flexion with imposed 8 Hz tremor.

EVALUATION OF GAIT ABNORMALITIES: A FUZZY CLASSIFIER BASED ON STATISTICAL GAIT ANALYSIS

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AIM: There is a wide variety of subjects affected by gait abnormalities, e.g. elderly, orthopedic patients, post-stroke patients, patients suffering from multiple sclerosis, Parkinson's disease, diabetes and others. In some cases, gait abnormalities may lead to an incremented risk of fall. The purpose of this contribution is to describe a method that allows to assign a score to the gait quality of a patient, based on gait parameters obtained from a simplified protocol of instrumented gait analysis.
METHODS: The patient is equipped with foot-switches and knee goniometers and is asked to walk at his/her preferred speed for 2-3 minutes, in order to collect approximately 100-150 gait cycles. Carrying out the test requires less than 15 minutes, comprehensive of patient preparation and signal acquisition. Then, specific qualitative and quantitative gait parameters are extracted from the computerized analysis of the gait cycles: the percentage of atypical cycles, the heel contact and push-off duration, the instability of the knee, the knee angular velocity at initial contact, the cadence. The instability of the knee during gait is evaluated from the dispersion of the goniometric curves recorded at each gait cycle, with respect to the average goniometric curve. Gait parameters are used as input variables of a fuzzy classifier: the value of each parameter is associated to a certain degree of membership to the class of "normal" or "abnormal" behavior. The rules defined for the fuzzy classifier allow to assign a score to the gait quality of the patient.
RESULTS: As an example of classification, Fig. 1 reports the scores obtained on a population of 27 patients suffering from type 2 diabetes. Patients were tested before and after the completion of a program of adapted physical activity that lasted three months.
CONCLUSION: The objective evaluation of patient's gait abnormalities allows to design rehabilitation protocols focused on the specific needs of patients and to obtain a quantitative documentation of the follow-up. The assignment of a synthetic score is a valuable tool in the validation of the efficacy of a specific therapeutic protocol and may be of help in the field of forensic and insurance medicine.

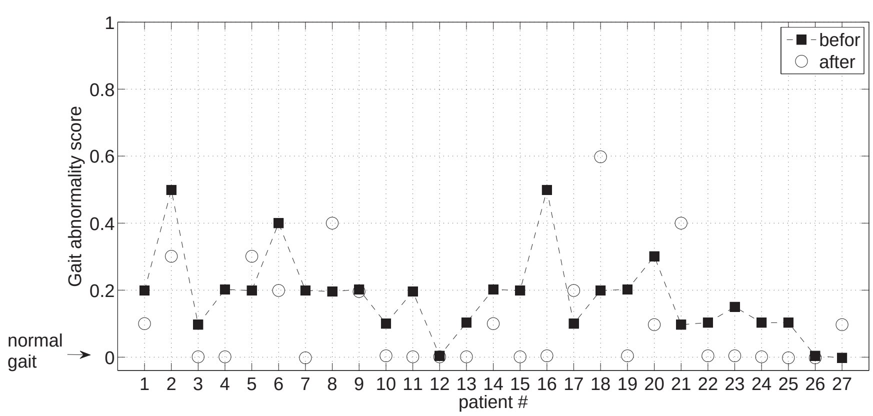

Figure 1: Population of type 2 diabetic patients: a gait abnormality score is assigned to each patient, before and after the completion of a program of adapted physical activity.

POSTURAL PARAMETRS IN VOLLEYBALL PLAYERS

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AIM: The purpose of this study is to examine the postural control in quiet stance of a group of volleyball players and to compare it with a population of healthy subjects.
METHODS: The postural control was investigated on a group of 51volleyball players and a control group of 50 healthy subjects. The acquisition protocol consisted of two different trials with the subjects in upright position with eyes open (OE) and closed (CE). At the beginning of each trial, the subject was asked to stand quietly on a force platform, arms at the side, and look straight ahead at a visual reference. The inter-malleolar distance was fixed at 4 cm and the feet opening angle was 30°. The experimental setup consisted of a Kistler 9286A force platform and of the acquisition card of the system STEP32 (DemItalia, Italy). Each acquisition lasted 60 s. The signal was recorded with a sampling frequency of 2 kHz and then down-sampled to 50 Hz. The major geometrical parameters were calculated from the CoP trajectories. More specifically, we considered Sway Path Length, Sway Area, RMS values of the antero-posterior, medio-lateral and resultant components, and the axes, eccentricity, and orientation of the smallest ellipse containing the stabilogram. We estimated the linear relation between stabilometric parameters and the Base of Support (BoS) area [1]. When a correlation between a specific parameter and BoS was found, the parameter was normalized.
RESULTS: The first result is that, even if the normalization is necessary from a methodological point of view, it did not bring significant changes in differentiating the two populations. Secondly, comparing the volleyball players and the control group, it was observed that most of the considered parameters did not differ. More specifically, only the RMS values, Mayor Axis and Minor Axis of the ellipse were found to be significantly different among the two groups. For these parameters the volleyball players show higher mean values than the control group, as reported by Table 1.
CONCLUSION: The postural control of the two populations differs mainly for the power related to the displacements of the CoP, that are significantly higher in volleyball players.

Table 1: Parameters significantly different (expressed in millimeters).

Group	**Volleyball players**		**Control group**	
	OE	**CE**	**OE**	**CE**
Antero-Posterior RMS	4.8±1.8	4.9±1.5	3.5±1.2	3.9±1.2
Medio-Lateral RMS	3.4±1.6	3.5±1.2	2.6±0.9	2.8±0.8
Resultant RMS	4.6±1.8	4.8±1.5	3.5±1.2	3.9±1.2
Major axis	24.9±7.8	26.6±7.6	18.7±5.1	21.5±6.4
Minor axis	14.9±4.8	16.4±5.2	11.9±3.6	13.7±4.1

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MODULATION OF JAW REFLEXES BY PERIODONTAL MECHANORECEPTORS AND MUSCLE SPINDLES DURING JAW MOVEMENT

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A chewing simulator device was used to investigate the question whether the reflexes from periodontal mechanoreceptors (PMR) and muscle spindles change during simulated mastication using normal adult volunteers. We delivered taps of 1N, 2N and 4N to the upper right incisor tooth at synchronized times when the mandible passed through the mid gape point of jaw separation,. The response of the jaw muscles to these taps were examined using the spike triggered averaging of the collected electromyogram (EMG). The dynamic measurements were compared to static tests which were also performed using EMG levels matching the ones achieved during the zero crossing phases of the dynamic tests. An inhibitory reflex that started at ~25ms and ended by ~40ms was evident from the collected data. The highest inhibition was observed at 4N stimulation intensity, at static condition, during jaw closing phase.
Once the experiment had been completed, a local anaesthetic solution was administered to the upper and lower peri-incisal periodontium and the incisive papilla, and all procedures were repeated.
In static condition with high background EMG the reflex response elicited by high stimulus (4 N) was inhibitory. After application of local anesthetic to the periodontal region the reflex response became excitatory. The periodontal reflexes initiated by 1N and 2 N stimuli during jaw closing phase were similar in both static and dynamic conditions.

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MUSCLE AFFERENT FEEDBACK DURING HEALTHY AND SPASTIC HUMAN WALKING

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The basic walking pattern is generated by a spinal network under the control of supraspinal structures. In addition, sensory feedback from the skin and the moving muscles plays a significant role in the regulation of the network activity and the locomotor movements. In humans, it is still unclear to which extent a spinal network is involved in the generation of walking and whether sensory feedback to the spinal cord plays a similarly significant role as demonstrated in animal models.

In clinical practice the dominant view is that the exaggerated tendon reflexes are responsible for muscle hypertonia which then leads to a spastic movement disorder. Consequently, most anti-spastic treatments are directed at reducing reflex activity. Today we know that no appropriate model exists for human spasticity, and some studies even suggest that spastic patients have reduced afferent feedback, which contributes to the impaired gait. Consequently, anti-spastic drugs should be applied with caution in mobile subjects. In most cases, their effects are cosmetic or might even hamper mobility by accentuating paresis.

In this presentation, some of the human locomotor studies will be reviewed by investigating muscle responses to unexpected stretches at the ankle joint in healthy and spastic humans. Via studies of the different muscle afferent pathways, a framework will be set up for the discussion of the possible contribution of muscle afferents through neural circuitries to the muscle control in healthy as well as spastic human gait.

SEPARATING CROSS-TALK FROM CO-ACTIVATION IN INTERFERENCE EMG RECORDINGS

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AIM: In complex musculature as that of the face, surface electromyograms (sEMG) are significantly confounded by activity of adjacent muscles, i.e. “cross-talk”. In this study we propose a novel method to remove cross-talk in interference signals by quantitatively correcting for cross-talk in estimating the true individual muscle activity.
METHODS: High-density sEMG was recorded in the lower face in 11 subjects. A set of muscle-selective motor unit action potentials (MUAPs) were extracted from each of four lower facial muscles. We quantified cross-talk as the MUAP amplitude ratio between the electrode positioned above the muscle to which the MUAP belonged and an adjacent electrode over another muscle. The mean cross-talk ratio (CTR) over different MUAPs for each muscle-electrode site combination were assembled in a 4x4 cross-talk matrix. Each row of the matrix describes how the potential at a certain electrode is composed by MUAPs from the four muscles: it is the weighted sum of the activity of each of the four muscles with the corresponding matrix row element as weighting factor per electrode. These CTRs can then be used in a matrix inversion algorithm to eliminate the cross-talk from these four electrode positions. The matrix inversion approach was empirically tested on data recorded during attempted isolated contractions of the four lower facial muscles.
RESULTS: The ability of the subjects to selectively contract the lower facial muscles was considerably under-estimated when using the raw measured EMG. This is exemplified when comparing Figure 1 part A to part B for attempted isolated contractions of the depressor labii inferioris (DLI, open bars) muscle.
CONCLUSION: Our approach corrects for most of the confounding activity of adjacent muscles on the estimate of individual muscle activity. The method assumes that only muscles included in the CRT estimate contribute to the measured signals, and that the MUAP set used to estimate the CTR is representative for the whole muscle. Imperfections in these assumptions are possible factors for cross-talk overcorrection, as for example indicated by the small “negative” activity obtained in some subjects (Figure 1B).

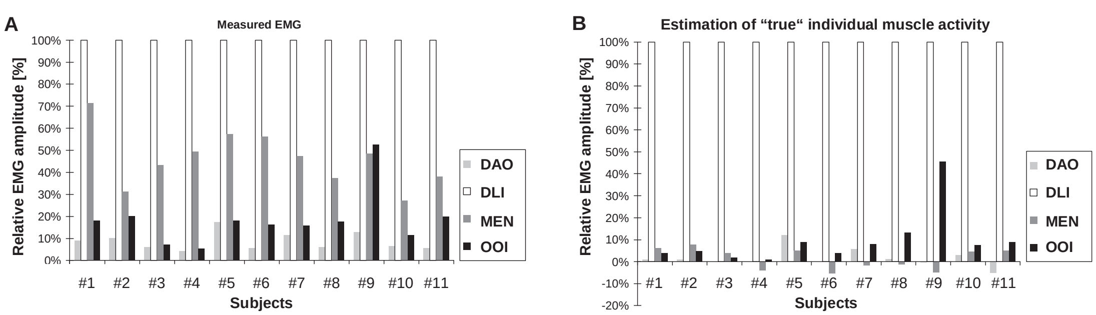

Figure 1: Comparison between measured EMG signals (A) and estimated “true” activity of the depressor anguli oris (DAO), depressor labii inferioris (DLI), mentalis (MEN) and orbicularis oris inferior (OOI) in 11 subjects. The experimental task was to selectively contract the DLI. Muscle activity was intra-individually normalized to the activity of the contracted muscle for better inter-individual comparison.

PAIN ALONE DOES NOT INTERFERE WITH MOTOR CORTICAL PLASTICITY

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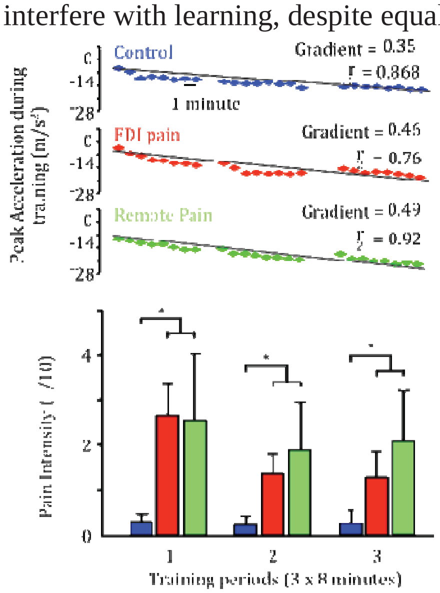
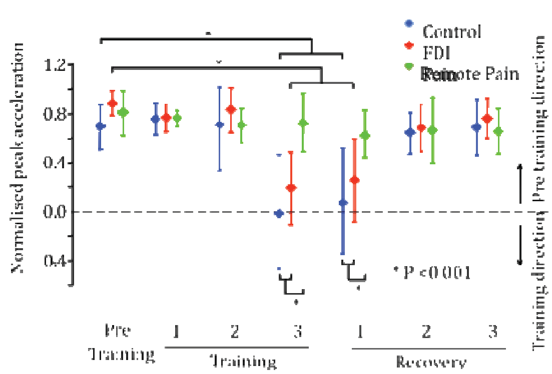
AIM: Short-term training of a novel task can induce motor plasticity of the corticomotor pathway. Training induced motor plasticity has been shown to be compromised by pain, but, decreased ability to perform motor training during pain may be responsible for this reduced plasticity. To investigate the effects of pain on training induced plasticity of the corticomotor pathway, with control of training performance and distraction from the training task by pain. METHODS: Transcranial magnetic stimulation (TMS) was delivered over the motor cortex of 9 volunteers to determine the optimal site to elicit index finger abduction movements. Subjects performed repeated index finger adduction movements (3x8 minute training sessions). Ten TMS stimuli (intensity =120% resting threshold) were applied to the same site before and immediately after each training sessions, and after 3x5 minute recovery periods. Acceleration of the index finger was recorded throughout the training and TMS periods. Training induced motor plasticity was measured by changes in TMS evoked finger acceleration after training in a control, local and remote pain condition. Pain (~3/10: Fig 1 bottom) was induced by a bolus injection of hypertonic saline into the FDI (local) and knee fat pad (remote pain) before each training session, isotonic saline was used (in the FDI) during the control. RESULTS: Subjects performed the training task equally between conditions (Fig 1 top). Peak acceleration of finger movement into abduction induced by TMS was reduced (P<0.01) following motor training into adduction during the control and local pain conditions, Fig 2. This change was not observed during the remote pain condition. CONCLUSIONS: When a training task is performed well during pain, pain alone does not interfere with motor plasticity. Distraction from the trained body part, by remote pain, can interfere with learning, despite equal performance of the training task.





Top left: Peak acceleration of the index finger during the training task improved equally during the 3x8 minute training sessions in all conditions. Bottom left: Pain induced in the FDI and knee (remote pain) was similar during the 3 training session. Top right: Training induced changes in TMS induced finger acceleration was observed in the control and FDI pain condition, but not in the remote pain condition.

GRIP FORCE CONTROL IN INDIVIDUALS WITH CARPAL TUNNEL SYNDROME DURING FUNCTIONAL TASKS

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AIM: Carpal tunnel syndrome (CTS) is the most common peripheral entrapment neuropathy and a frequent cause of disability in the upper extremity. Individuals with CTS usually presents with a range of symptoms including numbness, tingling, pain, and fatigue involving their hands and finger digits at the radial side. Although motor impairments is self-perceived during their daily life manual activities, little is known about how these individuals control their grip forces during these activities. Thus, the aim of this study was to investigate the grip force control in individuals with CTS.
METHODS: Thirteen right handed females (table 1) diagnosed with CTS and a group of matched control individuals participated in this study after sign an approved inform consent. They were instructed to perform a functional manual task of drinking using an instrumented cup (431 g) in normal conditions and when fatigue was induced on their hands. From grip forces and movement acceleration data measured, respectively, with a force sensor and a triaxial accelerometer attached to the cup, the following variables were calculated: 1) peak of grip force (PGF; N), 2), force ratio (FR), peak of load force ($LF_{max.}$ N), 3) time to reach the peak of the grip force (TimeG), and 4) time difference between the peak grip force and maximal load force (TLAG; in milliseconds).
RESULTS: Individuals with CTS applied higher grip forces (PGF and FR) than controls subjects to perform a manual task of drinking. However, the temporal variables of grip control were preserved (TimeG and TLAG). Furthermore, the fingers and hand fatigue has affected more adversely the grip force adjustment in individuals with CTS.
CONCLUSION: Individuals with CTS demonstrated impairments in grip force control when performing a functional task of drinking. These observed alterations may affect negatively their peripheral neuropathy increasing the CTS symptoms.

Table 1: Characteristics of the individuals with CTS

No.	Age (years)	Evaluated hand	Time since diagnosis (years)	Clinical Tests		BCTQ		SWT (Threshold)
				Phalen	Tinel	SYMP-score	FUNC-score	
1	35	Right	3	+	+	4	4	3.61
2	35	Right	1	+	+	4	4	>6.65
3	39	Right	<1	+	+	4	4	4.31
4	40	Right	<1	+	+	4	3	3.61
5	55	Right	5	+	+	4	4	>6.65
6	37	Right	3	+	+	4	5	>6.65
7	54	Right	1	+	+	4	4	4.31
8	43	Left	6	+	+	4	4	>6.65
9	38	Left	<1	+	+	3	4	3.61
10	51	Right	3	-	-	2	2	3.61
11	49	Right	7	+	+	4	4	3.61
12	53	Right	4	+	+	4	4	4.31
13	37	Left	<1	+	+	4	4	3.61
Mean	43.54± 7.70							

Boston Carpal Tunnel Questionnaire (BCTQ), symptom severity score (SYMP), -score - functional status score (FUNC), Semmes–Weinstein monofilament test (SWT).

EVALUATION OF CROSS TALK BETWEEN ADJACENT MUSCLES IN FELINE EMG RECORDED USING IMPLANTABLE MYOELECTRIC SENSORS (IMES)

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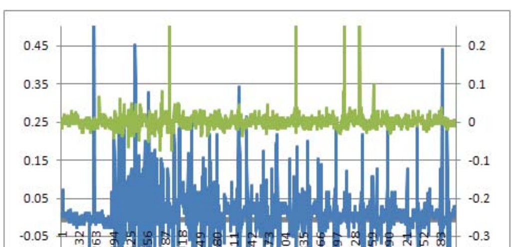
AIM: Practical operation of multiple degree of freedom (MDOF) prosthetic hands based on myoelectric control signals is currently limited by the availability of independent control sites. The use of a wireless, implantable system should allow the patient to take advantage of the benefits of an intramuscular system while obviating many of the risks associated with current wired intramuscular systems. However the issue of intramuscular crosstalk has yet to be addressed in regards to a completely implantable system.
METHODS: In this experiment three IMES capsules were implanted into the ankle extensor muscle group in the cat (calf muscles); Lateral Gastrocnemius (LG), Medial Gastrocnemius (MG), and Soleus (S). The extensor muscle group was surgically exposed, leaving all major nervous and vascular structures intact. A cuff electrode was placed around the tibial nerve before the branching plexus of the tibial nerve to form MG and LG-S nerves. Each IMES was implanted into the belly of the target muscle with the long axis of the IMES oriented parallel to the direction of action of the muscle fibers. The animal is then decerebrated per Heckman et al., 1994. The crossed extension reflex was activated by administering painful stimuli to the contra-lateral hind paw of the. The reflex causes the muscles to contract generating natural EMG signals as a consequence. Multiple crossed extension events were recorded. The MG branch of the tibial nerve was severed to remove all stimulus to the MG. The crossed extension reflex protocol was repeated to record signals going only to the LG and Soleus.
RESULTS: The recorded data was processed by visually identifying each crossed extension reflex event – each event was sectioned into a manageable data window and detrended by subtracting the window average. the RMS value of each channel of windowed data is then calculated. After denervation it was found that the RMS value of the active MG data EMG (21mV) was only 1.5 times the RMS value of the baseline ‘quiescent’ MG EMG data (14mv), while active LG RMS (60mV) value was 4.3 times the resting RMS value (14mV).
CONCLUSION: The crosstalk signal found in the MG is roughly 20% of the ‘active’ signal found in the LG - twice the predicted value from Lowery (Lowery et al., 2006), however there are subtle differences in physical geometry. Further long term cat experiments where the implant surgery is allowed to heal show co-activation/crosstalk EMG RMS values occurring at 5% of the ‘peak active’ signal.



Top trace – MG Bottom trace – LG. EMG traces in mV. One second of data shown.

Heckman CJ, Miller J, Munson M, Paul K, Rymer WZ (1994) Reduction in postsynaptic inhibition during maintained electrical stimulation of different nerves in the cat hindlimb. Journal of Neurophysiology:2281-2293.
Lowery MM, Weir REF, Kuiken TA (2006a) Simulation of intramuscular-EMG signals detected using implantable myoelectric sensors (IMES). IEEE Transactions on Biomedical Engineering 53:1926-1933.

FOUR-CHANNEL NEUROMUSCULAR STIMULATOR DESIGNED FOR ELDERLY PEOPLE

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AIM: A stimulator for neuromuscular electrical stimulation, to suit especially the requirement for elderly people with reduced cognitive abilities and coordination, was designed. The ageing of skeletal muscle is characterized by a progressive decline in muscle mass, force and condition. Muscle training with neuromuscular electrical stimulation reduces the degradation process. The discussed system is intended for stimulation of the posterior and anterior thigh.
METHODS: The core of the stimulator hardware is a multi-processor structure where each output-stage is controlled by its own microprocessor (PIC18, Microchip). An output transformer is used to keep the electrodes potential-free. A central controller unit (PIC24) allows using the stimulator as a stand-alone device. To set up the stimulation sequences and the trainings program and to evaluate the compliance data a PC is connected to the stimulator via wireless data link (ZigBee or Bluetooth). A graphical user interface software written in Visual Studio 2008 (Microsoft) allows high flexibility.
RESULTS: Hardware elements are shown in a block diagram in Figure 1. The stimulator has four biphasic constant voltage stimulation channels. Additionally, each channel has an analog input to measure the evoked myoelectric signal (M-wave).
CONCLUSION: To help elderly people to handle the stimulator by themselves the user interface is reduced to four input buttons, start / stop training and increase / decrease of the stimulation amplitude. For safety reasons, the electrode impedance is measured during stimulation. A further implementation of a smartphone will allow online monitoring of the stimulation process.
ACKNOWLEDGEMENT: This work was supported by the European Union, EU-Intereg IVa 2008-2013: N00033

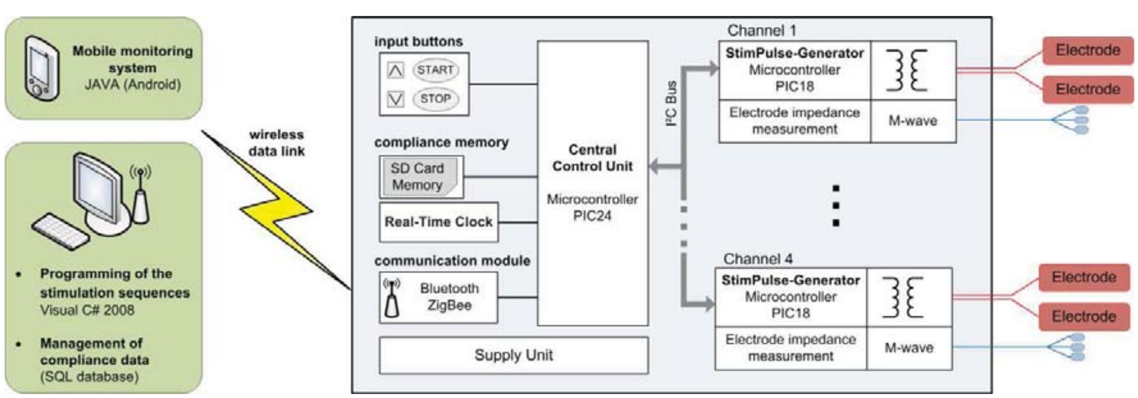

Figure 1: Block diagram of the electrical stimulation system.

MYOELECTRICAL ROBOTIZED ELBOW

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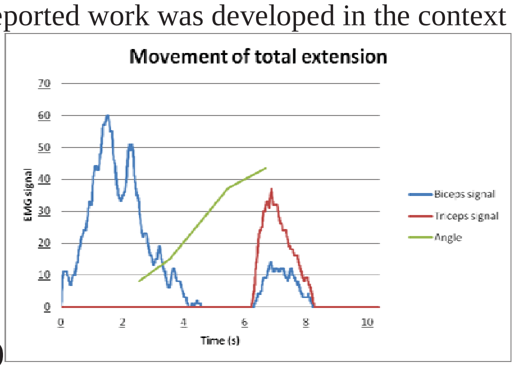
AIM: Study and develop a prosthetic device with a robotic elbow, where movements are determined by myoelectrical signals generated by the biceps (agonist muscle) and the triceps (antagonist muscle).
METHODS: Myoelectrical signals are analyzed, producing the flexion and extension of the device's articulation. The myoelectrical signal is picked-up by placing 2 pairs of electrodes on the longitude of the muscles. Once the signal reaches the circuit, the information of each muscle´s electrodes is amplified by specifically developed instrumentation amplifiers. There are other amplifiers that reference each pair of electrodes common-mode components and the body. These signals are high pass filtered with a cutoff frequency of 15Hz and rectified by means of a precidion full wave rectifier, then low pass filtered with a cutoff frequency of 1KHz. The subtraction of the resulting signal of each muscle returns a bipolar signal indicating the dominant sense of the contraction. The outcoming signal is then sent to a pulse-width-modulator that activates a servomotor, which actuates the prosthesis. The whole system consumption is supplied by 8 AA batteries, in a total of 12V. The prosthetic device built for this study is constituted by 2 light segments, connected to the servomotor in the articulation corresponding to the elbow.
RESULTS: The circuit was able to amplify the signals and attenuate the noise, making it possible to activate the servomotor, which made the extension or flexion of the two segments of the arm. Some difficulties were found in fixing middle positions between full extension and full flexion of the arm. Figure 1, a) and b) show example time waveforms of signals from the muscles during tests with the system.
CONCLUSION: This project was created with the intent to study the acquisition and processing of signals that make a prosthetic device work and to check the correctness of the biomechanical equations. As so, this project still needs to be improved in order to be usable by an amputee, not only in the physical appearance but also in the control of the device and choice of materials to implement the device in these situations. One of the aspects still under development is the blocking of the device in situations of hard force required from the prosthesis and its control strategy. A functional prototype was built and can be demonstrated and despite the limitations is serving as a starting point for future developments.
ACKNOWLEDGEMENT: The authors acknowledge the support from Nuno Sousa (Eng.) at the Instrumentation and Electronics Laboratory of the Department of Electrotechnical and Computer Engineering Department and the Directorate of the Bioengineering Masters Couse of FEUP. The reported work was developed in the context of an academic open project in Bioengineering.

a)


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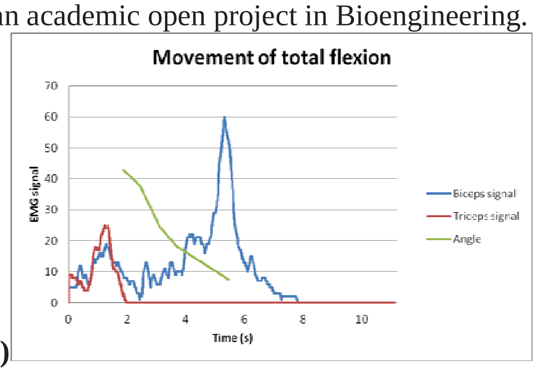

Figure 1: Signal excursions from the biceps (blue) and triceps (red) during a **a)** total extension and **b)** total flexion.

JOINT DYSFUNCTION AS A FORM OF ALTERED AFFERENT INPUT: PART II: CHANGES IN MOTOR CONTROL FOLLOWING SPINAL MANIPULATION AND EXERCISE

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The effectiveness of spinal manipulation in the improvement of functional ability has been well established by outcome-based research. However, the neurophysiological mechanisms responsible for the restoration of functional ability after spinal manipulation are not well understood. Research to date has shown that spinal manipulation can induce changes in various aspects of CNS functioning including alterations in reflex excitability, somatosensory evoked potentials, and cognitive function. One theory as to how this may be occurring is that spinal dysfunction, results in altered afferent input to the CNS, which in turn may lead to altered somatosensory processing; sensorimotor integration and motor control.
This talk reviews our work using showing changes in motor evoked potentials and electromyographic findings such as the flexion relaxation phenomenon and feed forward activation following joint manipulation.

JOINT DYSFUNCTION AS A FORM OF ALTERED AFFERENT INPUT: PART I: SENSORY PROCESSING CHANGES FOLLOWING SPINAL MANIPULATION

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The effectiveness of spinal manipulation in the improvement of functional ability has been well established by outcome-based research. However, the neurophysiological mechanisms responsible for the restoration of functional ability after spinal manipulation are not well understood. Research to date has shown that spinal manipulation can induce changes in various aspects of CNS functioning including alterations in reflex excitability, somatosensory evoked potentials, and cognitive function. One theory as to how this may be occurring is that spinal dysfunction, results in altered afferent input to the CNS, which in turn may lead to altered somatosensory processing; sensorimotor integration and motor control.
This talk reviews our work using somatosensory evoked potentials showing altered sensory processing following repetitive activity and joint manipulation.

NERVE PARATHESIA AFFECTS TRANSFER OF A VIBROTACTILE MORSE CODE LETTER ACQUISITION TASK TO MOTOR PERFORMANCE

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AIM: Although a frequent clinical complaint, quantitative measurement of the effects of paresthesia on limb sensation and perception are understudied. Paresthesia represents a form of altered afferent input which may have effects on sensory learning and processing of somatosensory information and subsequent motor performance. The aim of this study was to determine if experimentally induced paresthesia impacts performance during a vibrotactile Morse Code letter acquisition task and subsequent transfer to motor performance.
METHODS: In a between participants experimental study, 18 healthy volunteers (18-31 y) naïve to Morse Code interpretation, received transcutaneous radiating ulnar nerve paresthesia at the right ulnar notch, or no paresthesia during letter acquisition trials. Vibration patterns representing 8 Morse Code letters were individually delivered randomly to the palmar surface of the right fifth digit's distal phalange. 8 letters were exhibited 6 times (48 presentations). Participants responded as to which letter was communicated, and augmented accuracy feedback was displayed. Participants were testing immediately after acquisition for letter retention and transfer. 48 hours later, delayed retention as well as transfer to a motor task requiring the participants to "tap" out the letter was tested. Dependent variables response accuracy and total response time were recorded. Local Ethical Board approval was in place.
RESULTS: A 2 Group(Paresthesia, No Paresthesia) x 6 Trial (1-6) ANOVA model, with repeated measures last factor indicated that Mean Total Response Time (TRT) decreased $F(5,80)=4.03$; $p = .003$ and Mean Response Accuracy improved over the six acquisition trials $F(5,80)=8.07$; $p < .001$ regardless of sensory condition. On learning Retention (N=16): 4 (Group) x 3 (Trial: Acq 6, Ret 1, Ret 2) ANOVA model, with repeated measures last factor, there was a Significant within group main effect: $F(2,24)=4.84$; $p = .017$ with the delayed retention increasing TRT compared to acquisition trial 6 regardless of sensory condition with no difference in response accuracy. In the motor performance Transfer condition (N=16):4 (Group) x 2 (Trial: Transfer 1, Transfer 2) ANOVA model, with repeated measures last factor: for TRT, there was a Significant Interaction between transfer test session and sensory condition: $F(3,12)=3.39$; $p <.05$ with an increase in TRT when first experiencing paresthesia during transfer compared to those who never experienced paresthesia. For Transfer Mean Response Accuracy (N=16): 4 (Group) x 2 (Trial: Transfer 1, Transfer 2) ANOVA model, with repeated measures last factor, there was a significant interaction between transfer test session and sensory condition: $F(3,12)=3.35$; $p <.05$ with those who did not experience paresthesia in retention demonstrating worse accuracy than those who did. There was a significant "Between groups" main effect found for sensory condition $F(3,12)=6.59$; $p <.01$, where those with no paresthesia at any point were less accurate than those who experienced paresthesia during the immediate transfer and delayed transfer.
CONCLUSION: Regardless of the acquisition context, paresthesia actually improves subsequent motor transfer performance accuracy. When paresthesia is first experienced during transfer it negatively impacts total response time when assessing immediate motor performance.

A WHOLE MUSCLE SEMG MODEL WITH AN ACCURATE RECRUITMENT STRATEGY

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AIM: A time-invariant surface electromyogram (sEMG) model, based on previous models [1, 2] and incorporating distributed variables and individual conduction velocity average and standard deviation values for different motor unit types has been implemented and tested. Signal features root mean square (RMS), mean power frequency (MPF) and zero crossings/s (ZC) were calculated on the simulated signals and these features were shown to be accurate when compared with experimental data [3]. However, many assumptions were made in the implementation of the model, particularly the uniformity of motor unit firing frequencies and the lack of motor unit recruitment order and thresholds. These assumptions are not accurate. The aim of this work is to overcome the abovementioned shortcomings and implement a model capable of simulating sEMG signals from whole muscles. The model should be accurate to experimentally acquired data and incorporate motor unit recruitment threshold strategies to ensure such accuracy is achieved. For this purpose, the outcomes of the work by Gydikov and Kosarov [4] was considered. In [4], action potentials were measured during voluntary contractions with needle electrodes and it was found that motor units (MUs) exhibit characteristic thresholds, which determine the order in which they are recruited for contraction. Generally, type I MUs are recruited at lower thresholds than type II MUs. In addition, the firing frequency of MUs depends upon the level of force being exerted. These firing frequencies range from 8-14 Hz (type I fibres) and 12.5 – 24.5 Hz (type II fibres).
METHODS: The model was simulated using the muscle parameters outlined in [3] and incorporating recruitment thresholds and variable MU firing frequencies developed from the results described in [4]. The model was verified by conducting experiments where the subject was asked to perform isometric contractions for 10 seconds at 30% and 50% maximum voluntary contraction (MVC). The sEMG was recorded using differential surface electrodes fixed 10mm apart, on the biceps brachii muscle. The average RMS, MPF and ZC for experimental data, simulated data using the model from [4], and simulated data using the model incorporating recruitment thresholds and varying MU firing frequencies were calculated.
RESULTS: The recruitment thresholds and varying firing frequencies incorporated into the model have not affected the relative amplitude (RMS) of the signal. The relative amplitudes between the simulated and experimental results remain comparable. The zero crossing values are closer to the experimental results than previously simulated data. The MPF values from this model remained largely unchanged and close to the experimental results.
CONCLUSION: This model is moving closer to simulating life-like results by modeling more accurate physiological processes.

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SELECTIVE CHANGES OF INTRACOTTICAL FACILITATION AND INHIBITION FOLLOWING REPETITIVE COLUNTARY MOVEMENT

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AIM: The mechanisms that underlie use-dependent cortical reorganization are not well understood. The results from several studies have suggested that intracortical inhibition plays an important role in central motor plasticity. The role of facilitatory changes is less well understood. The aim of this study was to investigate changes in the intrinsic facilitatory and inhibitory interactions within the sensorimotor cortex subsequent to a period of repetitive voluntary contractions using transcranial magnetic stimulation (TMS).
METHODS: Motor evoked potentials (MEPs) and cortical silent periods (CSPs) were recorded from the abductor pollicis brevis (APB) and the extensor indices proprios (EIP) muscles of the dominant limb following single pulse TMS of the contra-lateral motor cortex in fourteen subjects before and after 20 minutes with no intervention, and again after a modified 20-minute repetitive typing task involving the index, middle and ring fingers. Short interval intracortical inhibition (SICI) and short interval intracortical facilitation (SICF) were also recorded from the same muscles using paired-pulse TMS stimulation following the control intervention and the typing task. To assess spinal excitability F wave persistence and amplitudes were recorded from APB following median nerve stimulation at the wrist and stretch reflexes were recorded from the EIP. Fatigue measures and motor training measures (typing speed and error rate) were also recorded before and after the typing task. Repeated measures analysis of variance (ANOVA) was applied separately for each of the TMS measures, M wave and Fwave data. Two-tailed paired t-tests were carried out on the motor training, fatigue and stretch reflex data.
RESULTS: There was a selective increase in SICF ($P<0.01$) and decrease in SICI ($P<0.01$) in EIP following the typing task. The opposite effect was observed in the relaxed APB following the motor training, with a decrease in SICF ($P<0.01$) and an increase in SICI ($P<0.01$). Typing rate increased ($P<0.001$) and error rate decreased ($p<0.05$) following the typing task. No changes were observed following the control condition. No changes were observed for the F wave response recoded from APB, or the short-latency stretch reflex component recorded from EIP. No changes in fatigue measures were observed.
CONCLUSION: The study found selective changes in SICF and SICI following a motor training task in both an involved and non-involved muscle. These changes suggest that as SICI is reduced in the active muscle following motor training, this also releases SICF in the same muscle, and that the opposite occurs in a relaxed muscle.

MOTOR TRAINING CHANGES PROCESSING OF EARLY CEREBELLAR AND CORTICAL SOMATOSENSORY EVOKED POTENTIALS

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AIM: Repetitive muscle activity results in a form of altered afferent input which is known to affect early somatosensory processing. The cerebellum is implicated in motor learning and it is important to be able to objectively measure changes in cerebellar processing as well as cortical processing with different motor tasks. The aim of this study was to investigate the effect of varying stimulation rate and the effects of a repetitive typing task on the amplitude of somatosensory evoked potential (SEP) peaks related to the cerebellar processing as well as cortical processing.
METHODS: SEPs (2000 sweep average) were recorded following median nerve stimulation at the wrist at frequencies of 2.47 Hz, 4.98 Hz, and 9.90 Hz from 12 subjects before and after a 20 minute repetitive typing task. Typing and error rate were recorded 2 minutes pre- and post-typing task. Effect of stimulation rate was analyzed with ANOVA followed by pairwise comparisons (paired t-tests) with Bonferroni corrections. Typing effects were analyzed by performing two-tailed paired t-tests.
RESULTS: Increasing stimulation frequency significantly decreased the N30 SEP peak ($p<0.02$). Both the 4.98 Hz 9.90 Hz rates were significantly smaller than 2.47 Hz ($p\leq0.01$). The N24 data significantly increased following the typing task for both 4.98 Hz and 2.47 Hz ($p\leq0.025$). In contrast, there was a highly significant decrease ($P<0.001$) in the N18 peak post typing at all frequencies. Typing rate increased ($P<0.001$) and error rate decreased ($p<0.05$) following the typing task.
CONCLUSION: Our results suggest that the N24 SEP peak is best recorded at 4.98 Hz since the N30 drops off and no longer contaminates the N24 peak, making the N24 most visible and easier to measure, while still enabling changes due to repetitive activity to be measured. The decrease in N18 along with an increase in N24 with no change in N20 suggests that the intervention lead to reduced inhibition at the level of the cuneate nucleus/inferior olives and a selective increase in the afferent information reaching the cortex via the cerebellum.

CHANGES IN LUMBAR MUSCLE ACTIVATION DUE TO PELVIC TILT

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AIM: This work aims to shed light on the complexity of back muscle pain development by means of a musculoskeletal computational model. Experimental studies (Dickx et al, 2008) have shown alterations in back muscle activation as a result of induced back pain. However, the changes of muscle activity in response to postural change are complex and for unilateral pain they are not confined to the ipsilateral side and they do not correlate with the level of pain. It is believed that changed muscle recruitment in patients influences the etiology and recurrence of low back pain. The mechanisms of these changes in muscle activity are still poorly understood.
METHODS: Postural changes of the pelvis tilt typical of one-sided back pain are imposed on an otherwise symmetrical computational model (de Zee et al., 2008) of a standing individual and the reconfiguration of muscle loads is monitored.
RESULTS: The model shows a complex increase of muscle activation levels for the model as a result of the postural change (Fig. 1). For branches of m. psoas major, m. quadratus lumborum and m. obliquus internus, the increase of activity level is significant from 0 to more than 5 percent. The increase of muscle activation concerns both sides of the body.
CONCLUSION: The study reveals that the relatively small asymmetrical postural change of Fig. 1 requires a complex reorganization of the muscle activation pattern. If the durability of the pain requires maintenance of the asymmetrical posture constantly, the constant of these muscles may lead to muscle infiltrations and increased and evolving pain.

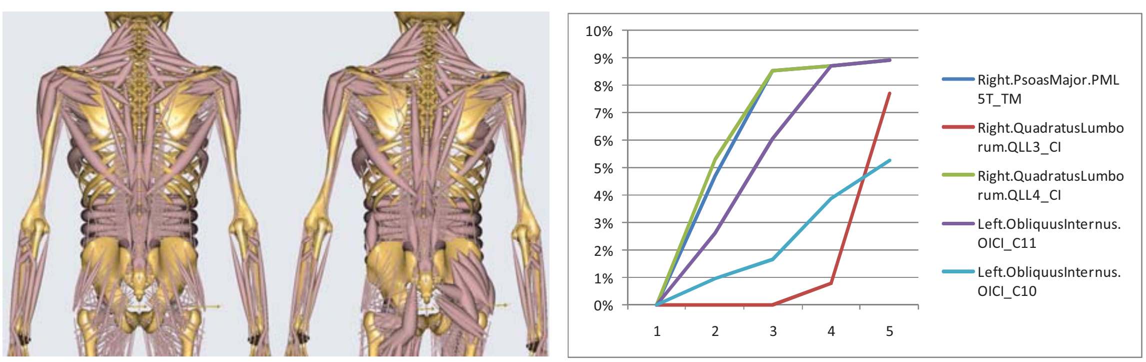

Figure 1: Illustration of muscle activation for symmetrical and changed posture. The graphs show the development of active state as a function of pelvic tilt in the five back and abdominal muscle fascicles with maximum change.

REFERENCES:
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Dickx N, Cagnie B, Achten E, Vandemaele P, Parlevliet T, Danneels L.: Changes in lumbar muscle activity because of induced muscle pain evaluated by muscle functional magnetic resonance imaging. Spine, 33, 983-989, 2008.

REPRESENTATION OF GAIT EVENTS IN DIFFERENTIAL ANGULAR ACCELERATIONS OF THE FOOT

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AIM: This study is part of a verification of a new wireless sensor system to identify gait events based on the 3D inertial difference recorded during rotation of limb segments. Accurate determination of gait events and phases is of interest in clinical applications and research projects, on the nature of gait and it is pivotal information in gait rehabilitation.
METHODS: A wireless sensor unit comprising two 3D accelerometers (ST LIS3) placed at a distance of 50 mm was attached to the foot, shank and thigh. The difference in acceleration and the binary foot contact events of the heel, the 5th metatarsal bone, and the big toe were sampled at 160 Hz, transmitted to a computer, and recorded to file. Four healthy subjects (male 28y, 33y and female 30y, 30y) walked along a straight 20 m path synchronous to a metronome at cadences of 70, 85, and 100 steps/min, while recordings were performed 3 times at each velocity after a period of initial training. The data was processed offline using Matlab®. Foot contact events were manually coded and weighted to discrete gait events of heel strike, foot flat, pre swing and toe off corresponding to the phases of loading response, mid stance, terminal stance and swing phase (Fig.1,2 red-dotted line). The 3 dimensional components of differential angular accelerations were rectified, added up, and low pass filtered by a moving average filter of 3 samples (Fig.1 blue line). Further, all recorded gait cycles were extracted and normalized to a common time scale to produce an averaged pattern (Fig.2).
RESULTS: The gait events heel strike and toe off were clearly visible as global and local maxima in single stride data (Fig.1) as well as in averaged data (Fig.2). The gait phase mid stance was a phase of a low, close to zero acceleration whereas the beginning of the swing phase was associated with a local maximum in the differential acceleration at toe off, followed by a plateau during swing.
CONCLUSION: The differential angular accelerations of the foot clearly indicate gait events and phases and might be suitable as input for an automated real-time gait event detection. Further investigations are ongoing and address the modulation of the presented pattern by cadence and sensor position at the shank and thigh.

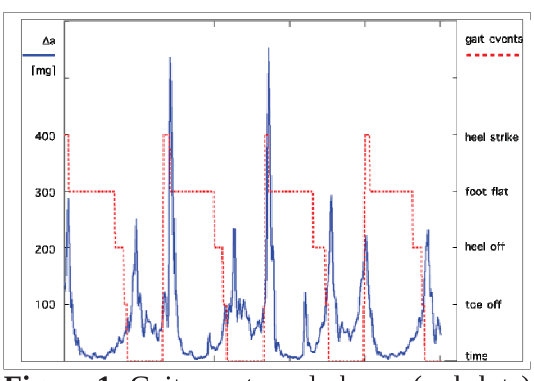

Figure 1: Gait events and phases (red-dots) vs. differential angular acceleration as rectified and summed signal of radial and tangential acceleration components (blue-line) at cadence of 70 steps/min

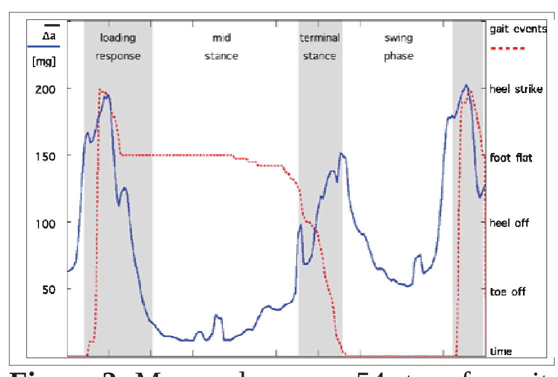

Figure 2: Mean values over 54 steps for gait events (red-dots) and differential angular foot acceleration (blue-line)

A COMPARISON BETWEEN SINGLE- AND MULTI-JOINT EMG-ASSISTED BY OPTIMIZATION LUMBAR SPINE MODELS

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AIM: EMG-assisted lumbar spine models represent invaluable tools for assessment of physical exposure. Recent studies demonstrated clear differences between single-joint EMG-driven and kinematics-driven finite-element (KD) multi-joint lumbar spine models. To further improve EMG-driven model predictions, a strategy to satisfy equilibrium at multiple lumbar levels was implemented for an EMGAO lumbar spine model and compared to its original single-joint version.

METHODS: Data were collected from one healthy male (52 yr, 1.745 m, 68.4 kg) during (1) symmetric full trunk flexion and (2) asymmetric lifting (5.2 kg in right hand) at four different heights (90, 120, 150, and 180cm) constrained vertically at constant sagittal and lateral horizontal distance to S1. Kinematics data were collected from 12 multi-LED clusters (feet, thighs, upper- and forearms, pelvis, T12, C7 and head) by a 4-sensor OptoTrak system (30 Hz). Ground reaction forces (GRF) were measured by a large custom-made force plate (1024 Hz). EMG signals were recorded (1024 Hz) from 12 DelSys active surface electrodes positioned bilaterally over longissimus, iliocostalis, multifidus, rectus abdominis, and oblique muscles. GRF and 3D kinematics data were input in the link segment model to estimate L5-S1 net joint loading. This net loading and linear envelope MVC-normalized EMG were then fed to the EMG-assisted by optimization (EMGAO) 76-muscle lumbar spine model to partition muscles forces and estimate joint forces. The single-joint model balanced the net joint moment only at L5-S1 while the multi-joint model balanced sequentially the net loading top-down across all the lumbar joints (T12-S1).

RESULTS: For the symmetric task, the multi-joint model predicted larger muscle forces in global extensors (iliocostalis and longissimus). At L5-S1, the difference between multi- and single-joint global extensor forces increased progressively from upright posture to reach a maximal value of 305 N at 60° of trunk flexion. The passive muscle force contribution dominated the last portion of trunk flexion. When all the extensors (global plus local) were taken into account, the active muscle forces acting at L5-S1 from the multi-joint model were superior by 538 N at 60° of trunk flexion. Except in full flexion, antagonist coactivity coming from the abdominal muscles was always larger for the multi-joint model, with difference going up to 400 N at 60° of trunk flexion. Compression and shear forces at L5-S1 followed the same trend as muscle forces. At 60° of trunk flexion, the multi-joint model predicted 34 % (854 N) additional compression and 31 % (196 N) more antero-posterior shear. The relative disparity was maximal at 20° of trunk flexion reaching respectively 44 % and 41 %. For the asymmetric task, differences between multi- and single-joint models were comparable to those obtained for the symmetric task. Global extensors were more involved in the mult-joint model with disparity between the two models increasing from the upper (T12/L1) to the lower lumbar spine (L5/S1) joints.

CONCLUSION: Present results confirmed previous comparisons made between KD multi-joint and EMGAO single-joint models: single-joint model violated the equilibrium at higher joints. Muscle and joint forces were underestimated by the single-joint model except near full flexion where passive muscle forces dominate.

TRUNK MUSCLE ACTIVITY DURING GAIT IN LOW BACK PAIN PATIENTS – THE RELEVANCE OF THE GUARDING HYPOTHESIS

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AIM: The aim of this study was to investigate whether subjects with chronic low back pain (CLBP) show differences in trunk muscle activity, reflected by a "guarding" mechanism during walking at different velocities and whether relationships exist between trunk muscle activity and cognitive variables. It was hypothesized that:

- "guarding" would be reflected by increased lumbar and abdomen muscle activity during all periods of stride and by relatively less relaxation during periods of swing compared to double support for the lumber muscle.
- greater walking velocity elicit greater increases in trunk muscle activity in the CLBP group compared to controls.
- higher levels of perceived fear and disability would be related to increased "guarding" and that pain coping strategies such as avoidance or persistent coping is also related to lumbar muscle activity.

METHODS: In a cross sectional study, sixty-three subjects with CLBP and 33 healthy controls walked on a treadmill at different velocities (1.4 till 5.4 km/h). Surface Electromyography (sEMG) data of the musculus erector spinae were obtained and smoothed rectified sEMG (SRE) values were calculated per period of swing and double support. The ratio of SRE values in swing to double support was used as a measure of relative relaxation (SRE ratio). Validated questionnaires were used to assess coping strategies (Dutch version of the Coping Strategies Questionnaire), disability levels (Roland Morris Disability Questionnaire) and fear of movement (Tampa Scale for Kinesiophobia). Random coefficient analysis were used to investigate the relationships between the questionnaires and sEMG values.

RESULTS: Results showed that, compared to asymptomatic controls, subjects with CLBP had increased muscle activity of the m.erector spinae and m.rectus abdominis, but not of the m.obliquus abdominis externus. These differences in trunk muscle activity between groups did not increase with higher walking velocities. SRE ratios of the back muscles were not significantly different between groups. There is no influence of disability or fear of movement on either SRE values or ratios however "Catastrophizing" was positively related to SRE values and "Distraction" was negatively associated with SRE ratios.

CONCLUSION: The observed increased lumbar and abdominal muscle activity in subjects with CLBP during walking supports the "guarding" hypothesis. Although at first glance the comparable SRE ratios between groups seem to be in contrast with the "guarding" hypothesis, the continuous higher levels of m.erector spinae activity in CLBP might indicate that the m.erector spinae do not have moments of total muscle relaxation. In addition in subjects with CLBP a maladaptive coping strategy like catastrophizing is related to increased lumbar muscle activity (i.e. "guarding"), and an adaptive strategy like distraction to increased variation between activation and relaxation of the lumbar muscles.

HOME MONITORING OF PATIENTS WITH PARKINSON'S DISEASE USING A WEB-BASED APPLICATION TO ACCESS WEARABLE SENSOR DATA

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AIM: There are two main requirements for remote monitoring of patients with Parkinson's Disease (PD): 1) a network platform that can efficiently manage available resources for reliable long-term monitoring and 2) a secure web-based interface that allows clinicians to remotely interact with patients and access sensor data. Herein we present our work 1) to develop a sensor network platform that efficiently utilizes available network resources with fine-tuning that is specifically performed to optimize its use for PD monitoring and 2) to implement a web-based application aimed at achieving remote access to the data.
METHODS: The sensor platform that we are using for this study is the Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability (SHIMMER). SHIMMER consists of a TI MSP430 microprocessor; a Chipcon CC2420 IEEE 802.15.4 2.4 GHz radio; a MicroSD card slot (up to 2 GB); a triaxial MEMS accelerometer. The device measures 1.75" x 0.8" x 0.5" and weighs just 10 g. SHIMMER sensors are integrated into a wireless body sensor network platform called Mercury. Mercury has been designed to support long-term, longitudinal data collections in the hospital and home settings and to overcome the core challenges of long battery lifetime and high data fidelity for long-term studies where patients wear sensors 12 to 18 hours a day. This requires tuning sensor operation and data transfers based on energy consumption of each node and processing data under severe computational constraints. To gain remote access to data recorded using the Mercury platform, we have developed a web-based application. The application allows a clinician to remotely interact with a patient (at home) through video conferencing over the Internet. In addition, the clinician has access to a live stream of the decimated version of raw sensor data. The full resolution sensor data is stored locally on the sensors and is later transmitted to the clinician for analysis. Data features are computed on the body sensor network nodes, wirelessly transmitted, and then analyzed to estimate clinical scores of the severity of PD symptoms.
RESULTS: We have performed extensive testing of the Mercury platform in combination with the above-described web-based application for remote access to the sensor data. Data analyses have allowed us to identify features derived from accelerometer data recorded using the Mercury platform that allowed us to estimate the severity of PD symptoms (according a clinical scale, the Unified Parkinson's Disease Rating Scale) with average accuracy of about 95%. We are currently performing a clinical study that leverages the Mercury platform and the above-described web-based application to assess longitudinal changes in the severity of symptoms in patients with late stage PD who experience severe motor fluctuations.
CONCLUSIONS: This paper presents the first system for remote monitoring of PD patients to assess longitudinal changes in the severity of PD symptoms. Such system can prove to be an invaluable tool in managing medication titration in late stage PD.
ACKNOWLEDGMENTS: This work was partially supported by the Michael J Fox Foundation.

DOUBLE DIFFERENTIAL RECORDING OF SURFACE EMG REDUCES CROSSTALK IN THE ASSESSMENT OF THE NOCICEPTIVE WITHDRAWAL REFLEX

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AIM: The aim of the study was to evaluate the efficacy of double-differential (dd) recordings of surface EMG to reduce crosstalk during the assessment of the nociceptive withdrawal reflex (NWR).
METHODS: 8 subjects participated in the study. Electrical stimulations were delivered at two sites under the sole of the foot for eliciting nociceptive withdrawal reflexes. Single (sd) and double differential (dd) surface EMG signals were recorded from the TA and SOL muscles. EMG signals from both muscles were also recorded by bipolar intramuscular wires (iEMG). The root mean square (RMS) amplitude was extracted 60-180 ms post stimulus. The RMS ratios between reflex and crosstalk were extracted for both sd, dd and iEMG recordings to compare the effect of dd recordings. Moreover, the cross correlation between the reflex EMG envelope and crosstalk envelope (10 Hz, LP filter) was extracted from the sd, dd and iEMG.
RESULTS: The RMS ratio between the sd recordings of the antagonistic muscles was significantly higher than the ratio between iEMG of the antagonistic muscles ($p<0.05$, t-test) – indicating that crosstalk is present in sd recordings. The RMS ratio between agonist (reflex) and antagonist (crosstalk) muscles was significantly lower using dd recordings compared to sd recordings ($p<0.05$, t-test), indicating less crosstalk. The correlation between reflex and crosstalk was significantly lower using dd recordings than when using sd recordings ($p<0.05$, t-test). The correlation between iEMG in the agonistic muscle and the antagonist dd recording was significantly lower than between the agonistic iEMG and the antagonist sd recording ($p<0.05$, t-test).
CONCLUSION: The RMS ratios indicated that crosstalk was present in the sd recordings. The results indicate that the application of double differential recording reduces crosstalk during the assessment of the NWR.

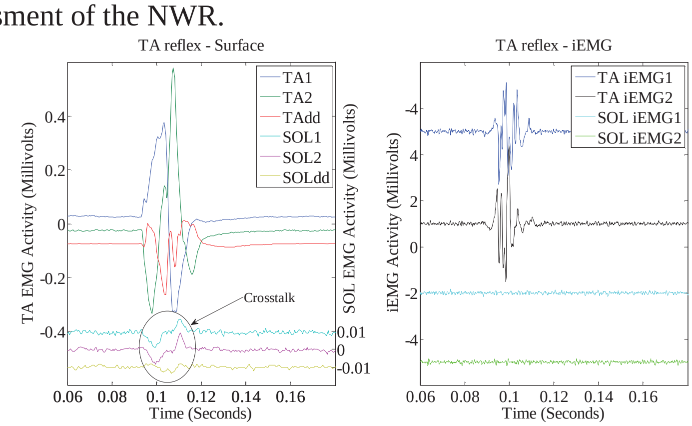

Figure 1: Surface EMG and intramuscular EMG (iEMG) during a TA reflex. The figure illustrates how the double differential recording reduces the crosstalk recorded in the SOL muscle. The SOL iEMG clearly demonstrates reflex activity in the TA muscle only. The signals have been offset slightly for easier viewing. Note different vertical axis for surface TA and SOL activity for the surface EMG. Stimulus start at Time = 0 seconds.

SELECTIVE ACTIVATION OF PIG MEDIAN NERVE USING A MULTIPOLAR CUFF ELECTRODE

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AIM: To investigate the selectivity in activating muscles in the forearm when using a multi-polar cuff electrode to apply electrical stimulation to a nerve trunk in the upper limb in pig.
METHODS: Acute experiments were performed in six anesthetized pigs. A multi-contact cuff electrode was implanted around the median nerve (six 0.5 x 0.5 mm contacts at 60° interval around the inner circumference at cuff center, 1 mm wide ring contacts at each end approx. 4 mm from the middle). Cathodal stimulation was applied with the center electrode contacts in longitudinal tripolar configuration (LTC) in all pigs, and transverse tripolar configuration (TTC) using shorted neighbor center contacts in three pigs. The stimulation selectivity was evaluated by recording EMG responses from epimysial electrodes placed on the selected forearm muscles: flexor digit. II (M1), flexor carpi radialis (M2), flexor digit. superficiales (M3: superficial belly, M5: deep belly) and flexor carpi ulnaris (M4) in all pigs, and also extensor carpi radialis (M6) and brachialis (M7) in three pigs. For each muscle, the peak-to-peak responses were normalized to the largest response of the same muscle. A selectivity index (SI) was calculated as the ratio between the normalized peak-to-peak response and the sum of all normalized muscle responses. An SI equal to 100% correspond to only one of the muscles being active.
RESULTS: Maximum SI for M1, M2, M4 and M5 ranged between 26% - 60%, whereas for M3, M6 and M7 they ranged 59% - 95%. We also observed that the SI's was the highest just above response threshold and then decreased because of muscle co-activation. Further, higher selectivity was obtained with the TTC stimulation configuration compared to LTC configuration but activation was lower (see Figure 1).
CONCLUSION: It was possible to activate different forearm muscles, but the degree of selectivity depended on a combination of fascicular organization relative to the electrode contact locations, stimulation current and stimulation configuration.
ACKNOWLEDGEMENT: This study was supported by the Danish National Advanced Technology Fund (J. 005-2005-1).

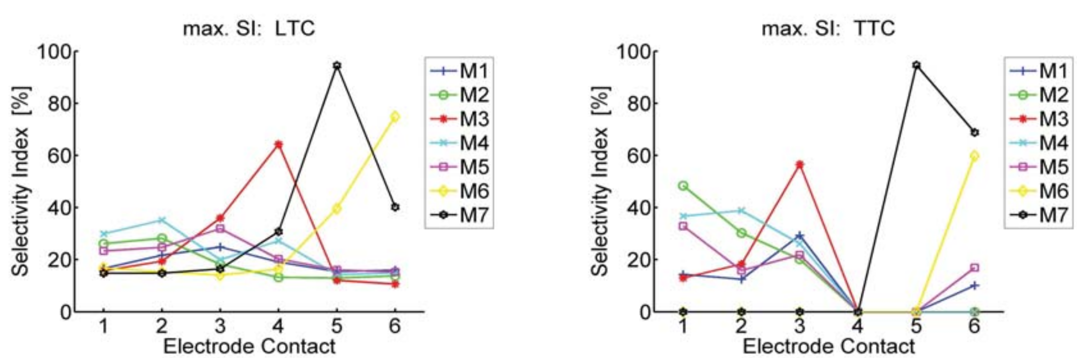

Figure 1: Example of maximum selectivity obtained per muscle for each of the six center electrode contacts for stimulation in LTC (left) and TTC (right) configuration in one pig.

BIPEDAL SUPPORT SURFACE ROTATIONS TO INVESTIGATE HUMAN BALANCE CONTROL

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AIM: Bipedal stance in humans is unstable and intrinsic muscle stiffness alone is not sufficient to counteract the effect of gravity. Humans have to actively maintain balance by generating corrective ankle torques, based on visual, vestibular and proprioceptive information. Here we investigated the proprioceptive contribution of the left and right ankle to human balance control.
METHODS: To investigate the contribution of each ankle we developed a device to apply support surface rotations for each ankle. The device consists of two small foot-size support surfaces on which subjects have to stand with the left and right foot. Ankle stiffness and proprioceptive feedback were investigated by applying rapid ramp-and-hold support surface rotations.
RESULTS: As a result of the minimum jerk profiles, the torque is flat between 100-150 ms after perturbation onset. The ankle stiffness can be estimated by dividing the differences in torque and angle (before vs. after perturbation); the stiffness of the ankles varied over the subjects between 79 and 169 Nm/rad.
CONCLUSION: The device is able to apply support surface rotations with high bandwidth, facilitating the measurement of the ankle stiffness with ramp-and-hold rotations. The combined stiffness of both ankles is lower than the critical stiffness imposed by gravity (≈600-700 Nm/rad). The measured stiffness reflects the intrinsic muscle stiffness as afferent feedback is unlikely to contribute to the torque within 100 ms after perturbation onset.

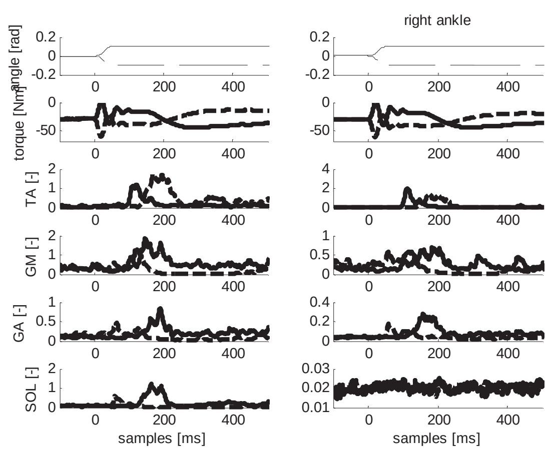

Figure 1: Left: a subject on the Bipedal Ankle Perturbator (BAP). The BAP consists of two support surfaces which can independently rotate in dorsi-/plantarflexion direction. The axes of rotation of BAP are aligned with the axes of rotation of the ankles. Right: typical response of a subject; the subject was instructed to lean forward. Solid lines show a condition in which the calf muscles are stretched (dorsi flexion); dashed: plantar flexion rotations (‘unloading’ the calf muscles).

VISUO-MOTOR SYSTEM ACTIVATION ON TARGET BASIS MOVEMENT COORDINATION

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AIM: human visual-motor system on the task of target reaching is stimulated to extreme hard task whenever obligatory trajectory corrections are introduced during the execution of the assignment. Experimental data obtained confirm the close information exchange among visual system, eye movement control, arm motor system and sensory control over reaching movement execution.
METHODS: target shift paradigm has been applied to eight healthy subjects. The target was a bright circle on a touch screen monitor, positioned at a normalized distance with arm length of each subject. The stimuli supply was announced by an attentive warning signal; each trial presentation occurred in a range between 2 seconds and 3.5 seconds; the target was randomly displaced on the monitor, in one the seven set position (a central one and three on each side). Target appearance timing and muscular activity were recorded on a multi-track EEG (29 EEG+ EOG + EKG) channels. Target switched randomly after 60, 130 ms from start.
RESULTS: the signal analysis was carried out with EegLab, this allowed the detection of ERP components implied in the visual presentation task, the movement execution, trajectory correction to the new shifted position and target reaching. The total duration took a minimum of 300 ms and a maximum of 600 ms; the time execution was prolonged if the target shifting was proposed in the very last moment, that is when the subject was almost touching the screen.
CONCLUSION: results suggest the possibility that the visual motor control relies on more complex interactions than a mere consecutive link between visual information and movement execution. Delay on trajectory correction was significantly more relevant when target shifting was triggered during last phases of execution. Gaze redirection on the target is exerted after deceleration of limb movement. This implies that peripheral visual field supply enough information about new target position to visual motor system. Once saccadic reflex allows pointing and target reaching.

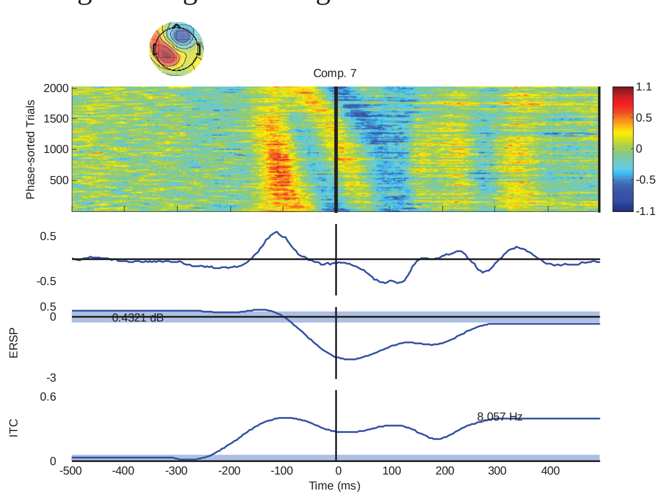

Figure 1: This graph illustrates the ERP, ERSP (erp spectral power) and ITC (inter trial coherence) with phase sorting of single trial at 8.057 Hz. Time at 0.0 ms represents the event of shifting of the target point.

MOTOR UNIT POTENTIALS WITH DISCRETELY VARYING LATENCIES: A PHENOMENON AWAITING EXPLANATION

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AIM: During high-density surface EMG recordings of single motor unit potentials (MUPs), we have occasionally observed a phenomenon that cannot be readily explained within our current understanding of a motor unit (MU). This paper aims to present these cases as well as some explanations that we thus far have considered (and rejected). We hope to generate the discussion that may lead to a plausible and testable hypothesis.
METHODS: We have observed thenar MUPs (activated through median nerve stimulation at the wrist or elbow) occurring at two or three discrete latencies. At low stimulus intensity, the MUP arrives at latency L1. At slightly increased intensity, it may alternate between L1 and shorter latency L2, at further increments it fires only at L2, and then (in one case) at even shorter L3 (see Figure 1). From high-density sEMG recordings and the pattern of activation, we are certain we are dealing with the same, stable, MUP. In Rotterdam, we have seen this phenomenon twice, once in an ALS patient and once in a patient with Guillain-Barré syndrome. Independently, it was found during investigations in Nijmegen, in a MU of two ALS patients. The phenomenon appears to be reproducible: on MU tracking, whereby we followed a MU over time, we found that one of the MUs in our study demonstrated this effect also in subsequent sessions, albeit at somewhat shorter latencies. We have never seen it in healthy subjects. The distal motor latency of the maximum CMAP is normal, but that of the MUP may be quite long, suggestive of slow nerve conduction in this particular axon.
CONCLUSION: We first considered the hypothesis that this phenomenon can be explained by excitation of a slightly more distal node of Ranvier through the increases in stimulus intensity. However, L2-L1 equals at least 1.5 ms, which represents (at a normal nerve conduction velocity of 50 ms) a distance of almost 8 cm: far too much for internodal distance. Secondly, we thought of demyelination in combination with the previous hypothesis, but because we have observed this effect primarily in ALS, this hypothesis seems unlikely.

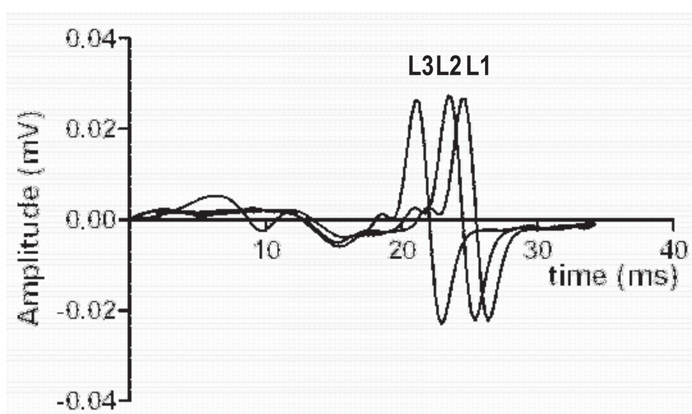

Figure 1: Example of MUP with three discrete latencies

THE MISMATCH NEGATIVITY (MMN) FOR IMPLICIT PERCEPTION PROCESS

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AIM: It has been known ever since Naatamen's early works (1978), that the human auditory system and more generally the central nervous system can detect differences in stimulation against a backdrop condition of repetitive noise/sounds ("change detection"). Using the odd-ball paradigm with audio stimuli we have been able to hypothetically quantify the possible capacity defect of change detection on temporal-insular cerebral damaged subjects.
METHODS: Using the event related potentials (ERP) on audio stimulation with frequency deviant stimuli, the early distinction components of deviant phenomena are identified (lower than 200ms), the distinction occurred also when the subject did not consciously pay attention to deviant audio phenomena. The odd-ball paradigm was used with frequency stimulus at 800 Hz lasting 100 ms and with a deviant stimuli of 1000 Hz lasting 100 ms. The ICA components have been retrieved with EegLab on a sample of 10 subjects with central or parietal cerebral damage and 10 subjects with temporal-insular damage.
RESULTS: The signal which identifies the process of "change detection" is defined "mismatch negativity" and represents the exact moment at which regular stimuli change occurs. In the control group containing subjects with damage distant from the temporal-insular region we did not find any MMN signal variation compared to healthy subjects of the same age (a first component at 110-120ms; a second component at about 130-140ms with wider magnitude in the deviant condition and a third positive latter component, similar to P300). In the control group with temporal-insular damage we detected varying degrees of alteration of the "change-detection" process leading up to complete termination (second and third component) in the absence of neurological focal deficits and auditory capacity perception deficits.
CONCLUSIONS: from intra-cranial recording studies of the signals produced by auditory stimulation with the odd-ball paradigm, one can see that the analyses of the characteristic physical stimuli (e.g. the acoustic frequency tone) occurs in the primary auditory cortex, area 41, where response to stimulus remains unaltered unlike area 42 where a reduction in response is found (magnitude reduction due to synaptic depression) due to repeated monotonous stimuli. The comparison of a perceived signal and a previous memory sign is processed in associative area 22. Many studies have been carried out to distinguish the temporal contribution from the frontal process of "change-detection", in particular, in dyslexic and in schizophrenic subjects where prefrontal contribution of MMN is lacking. In our records we point out how structural alteration involving frontal-temporal connections systems (inferior longitudinal fasciculus) can play a decisive role on the abolishment of the prefrontal MMN component by the odd-ball auditory component.
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EFFECTS OF TRANSCRANIAL DIRECT CURRENT STIMULATION ON MOTOR NETWORK CONNECTIVITY IN RESTING STATE FMRI

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AIM: Transcranial direct current stimulation (tDCS) is a promising technique to non-invasively study and alter human brain function by sending a weak direct current through the skull and brain via two electrodes on the scalp. Dependent on the direction of the current, this stimulation can either increase or decrease neural excitability in the cortex and its effect can outlast stimulation for up to one hour. This, together with being a safe, cheap and mobile technique, makes tDCS a candidate for the clinical treatment of several neurological disorders, such as Parkinson's Disease and ALS. Unfortunately not much is known about the mechanism behind the tDCS induced alteration of cortical excitability and the effects of this stimulation inside the brain. We are, for the first time, using resting-state functional magnetic resonance imaging (rs-fMRI) to investigate the effects tDCS exerts on the functional connectivity networks in the brain. Our main focus is on the motor network.
METHODS: Transcranial direct current stimulation is administered, according to usual practice, with the anode over the left motor cortex and the cathode over the right eyebrow. The constant current of 1 mA is applied for 15 minutes, on 30 healthy subjects. The effect of this stimulation is assessed by rs-fMRI scans before and after stimulation. In rs-fMRI spontaneous low-frequency (<0.1 Hz) fluctuations of the blood oxygenation level dependent (BOLD) signal throughout the brain are recorded, while the subject is resting but awake. We use several techniques, such as graph theory and independent component analysis, to extract from these recordings the cortical connectivity patterns in the brain. Such a connectivity map is constructed for each measurement session (i.e. before and after tDCS) and we assess the changes the stimulation has induced between the two maps. The same procedure is followed for 15 minutes of sham tDCS, and the effects on connectivity patterns of real and sham tDCS are compared. We also compare for the real and sham conditions a regression analysis of the averaged BOLD signal of the motor cortex with other areas in the brain.
RESULTS: We are currently in the process of measuring 25 subjects; all remaining measurements have been scheduled in the coming two months. Due to the subtleness of the expected effect, we will not draw conclusions before measurements are finalized. Nevertheless, the proven significant neural excitability alterations by tDCS in the (motor) cortex strongly suggest that changes in motor network connectivity should accompany this effect. We are therefore convinced that our study will detect these changes and lead to new insights on the workings of a promising neurostimulation technique.

SHORT RANGE STIFFNESS OF THE IN VIVO **HUMAN WRIST EXTENSORS AND FLEXORS**

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AIM: Short range stiffness (SRS) is a mechanical property of muscles and is characterized as a high stiffness within a short range of muscle lengthening. SRS is assumed to be the result of lengthening of attached cross-bridges prior to forced release. Thus far, SRS has been estimated mainly on isolated mammalian muscles. In this study we present a method to estimate SRS of the human wrist extensors and flexors in vivo.
METHODS: Wrist rotations (0.15 rad, 3 rad/s) were imposed at eight levels of voluntary contraction ranging from 0 – 2.1 Nm by means of a single axis manipulator. Flexion and extension SRS of the wrist joint was estimated using a dynamic nonlinear model that was fitted onto the recorded wrist torque (Fig. 1).
RESULTS: For all subjects and torque levels the model was able to describe the recorded torque well, with mean VAF>99%. Values for SRS and the elastic limit range were found reliably and consistently (Fig 1,A:C). Except for low initial torque values of $T_0 < 0.6$ Nm, parameter variation over repetitions was low. For the majority of subjects a strong correlation ($\rho>0.8$) between SRS and EMG was found (Fig 1,D).
CONCLUSION: SRS allows for an estimation of the number of coupled cross-bridges and thus, the contribution of contractile (muscle) tissue to joint stiffness. Results corresponded quantitatively with results from previous studies on isolated muscle and in vivo joint measurements. The method is potentially useful to estimate the force of antagonistic muscles which is impossible from sole measurement of joint torque and difficult from EMG recordings alone.

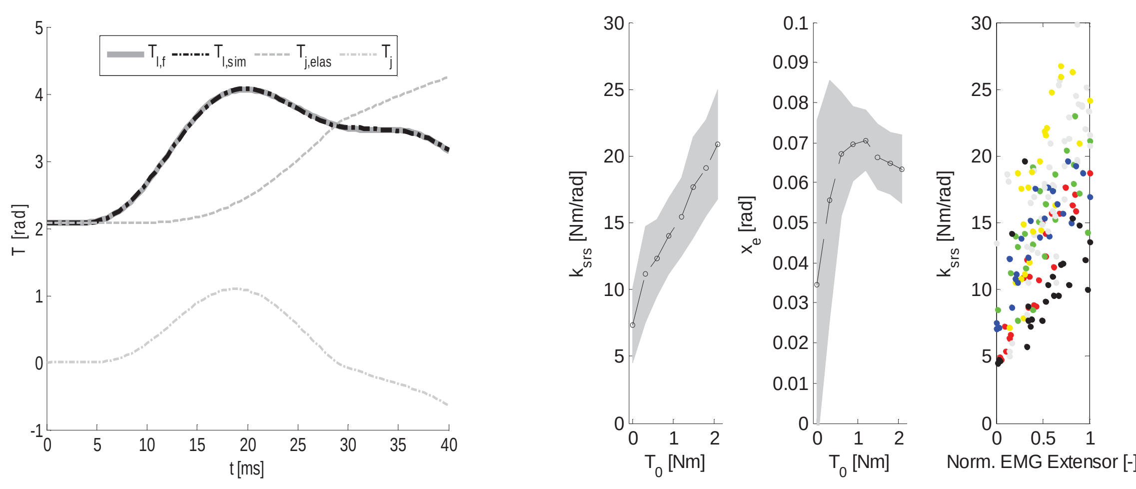

Figure 1 A: optimization example. $T_{l,f}$: recorded lever torque (filtered) $T_{l,sim}$: simulated lever torque, $T_{j,elas}$: simulated elastic muscle torque, T_j: simulated resultant joint torque
B,C: Extensor parameter results for SRS (k_{srs}) and elastic limit range (x_e), (n=9), grey=1SD.
D: Scatter plot of k_{srs} w.r.t. normalized EMG measurements, colors denote subjects (n=7).

MYOELECTRIC CONTROL OF A CYBERNETIC HAND

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AIM: A study was conducted on five healthy persons to see how well they could myoelectrically control a prosthetic hand. This to see how well a prosthetic hand could be controlled in real-time. We also investigated if random selected movement were harder to perform compared to a prior known movement protocol.
METHODS: The participants were instructed to perform the seven different movements synchronously with both hands. Simultaneously, myoelectric signals were recorded using eight bipolar surface electrodes from the right forearm of the participants and joint positions were recorded from the left hand using a data glove. These signals would form the input and output respectively to a pattern recognition algorithm. The algorithm used was local approximation using KNN. The output joint positions were processed to become control signals for the Cyberhand robotic hand. The first session was a supervised learning session in which the pattern recognition algorithm learns to associate EMG-signals with joint angles. The second session was an evaluation session to assess how well the system performed. These sessions were performed three times and each movement was performed three times consecutively within each session. Between sessions learning data was cleared. After the final evaluation session a random evaluation session was performed in which the movements to be performed were chosen at random.
RESULTS: The results from the final evaluation session and random evaluation session can be seen in Figure 1. The average accuracy for the final evaluation session was 88% and for the random evaluation session 86%.
CONCLUSION: The results show that the participants were able to perform seven different movements to an accuracy of 86% in the random evaluation session. Furthermore it did not seem to be any difference in performing random movements compared to fixed scheme protocol. This indicates the algorithm to be a viable candidate for intentional myoelectric control of a dexterous prosthetic hand.
ACKNOWLEDGEMENT: This work was supported by the SmartHand project (NMP4-CT-2006-0033423).

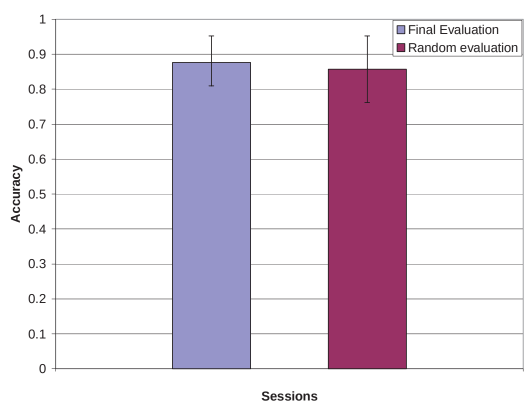

Figure 1: Results for the Final Evaluation and Random Evaluation sessions.

CLINICAL AND ELECTROMYOGRAPHIC ASSESSMENT OF TMD TREATMENT WITH OCCLUSAL SPLINT.

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AIM: The purposes of this study were to investigate patients with temporomandibular disorders (TMD), correlating clinical data and electromyographic (EMG) findings before and after treatment with an occlusal splint, and to compare EMG data in patients with those of an asymptomatic group.
METHODS: Data were collected immediately after splint adjustment, after one and five weeks of treatment.
RESULTS: After treatment, significant variations ($p<0.05$) were found in mouth opening and in pain remission. Immediately after splint adjustment, masseter muscle symmetry and total muscular activity were significantly different with than without the splint ($p<0.05$), showing an increased neuromuscular coordination. There were no significant differences between the three sessions, either with or without splint. There were significant differences between TMD and control groups for all analyzed indices of muscular symmetry, activity and torque, except total muscular activity.
CONCLUSION: Splint promoted the balance of EMG activities during its use, relieving symptoms. EMG parameters identified neuromuscular unbalance, and allowed an objective analysis of different phases of TMD treatment differentiating individuals with TMD from asymptomatic subjects.

Table 1: EMG indices in 15 patients with TMD and in 15 control subjects. Control: control subjects; TMD 1: at the beginning of the treatment, on the day of splint deliver; TMD 2: after 1 week of splint use; TMD 3: after 5 weeks of the splint use. In each stage, tests were made with (w) and without (w/o) the splint; POC: percentage overlapping coefficient (index of left-right muscular symmetry); TORS: torque coefficient (potential lateral displacing component); ATTIV: relative activities of masseter and temporalis muscles; Comparisons were made by paired Student's t tests.

		POC t	POC m	TORS	ATTIV	Muscular activity
		(%)	(%)	(%)	(%)	(μV/μV x 100 x s)
Control	Mean	88.83	88.23	8.09	4.71	102.33
	SD	1.25	1.12	0.64	2.52	27.97
Difference (TMD1w-TMD1w/o)	Mean	1.48	3.04	-0.23	6.54	-18.00
	SD	3.31	5.40	2.17	13.26	22.08
P (t paired)		NS	0.047	NS	NS	0.007
Difference (TMD2 w-TMD2 w/o)	Mean	2.57	2.88	-2.71	-3.86	-6.20
	SD	6.94	7.91	7.50	13.41	35.88
P (t paired)		NS	NS	NS	NS	NS
Difference (TMD3 w-TMD3 w/o)	Mean	1.95	3.54	-0.32	-2.16	-9.53
	SD	2.48	6.58	1.52	10.27	25.29
P (t paired)		0.009	NS	NS	NS	NS

SENSORY FEEDBACK SYSTEM FOR A SENSORISED PROSTHETIC HAND

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AIM: The aim of this study was to see how well able-bodied participants could discriminate location of stimuli and different levels of pressure on the volar aspect of the forearm . This to mimic a possible sensory feedback system for a sensorised prosthetic hand.
METHODS: Digital servomotors were used as actuators to provide different levels of pressure and to stimulate different locations on the forearm of 11 healthy individuals. Stimulations were provided using a custom software application made in LabView and associated hardware for control of the actuators. Two tests were performed, one to test the participants ability to discriminate between different stimuli locations on the forearm and the second test was to see how well participants could discriminated five levels of pressure applied to a single site of stimulation. Each test was divided into three phases, were in the first phase the participant got acquainted with the system. The second phase consisted of a reinforced learning phase were the participants guessed the stimuli location or level and got informed of the right answer. The final phase was an evaluation phase were the participants guessed the stimuli location or level. In all phases of the test the participants wore earmuffs to prevent motor noise to from influencing the results.
RESULTS: The individual results of the two different tests are shown in Figure 1. Participants were able to differentiate location of stimuli with a mean accuracy of 82% and levels of pressure with a mean accuracy of 79%. Location seemed to be easier to discriminate then pressure level.
CONCLUSION: The results show that it is possible to provide sensory feedback in this way, which allows for discrimination between different sites as well as different levels of pressure. The system is intended to be used by amputees with a myoelectric prosthesis equipped with tactile sensors. This experiment is a first step to evaluate the principle on healthy participants before it is tested with amputees.
ACKNOWLEDGEMENT: This work was supported by the SmartHand project (NMP4-CT-2006-0033423)

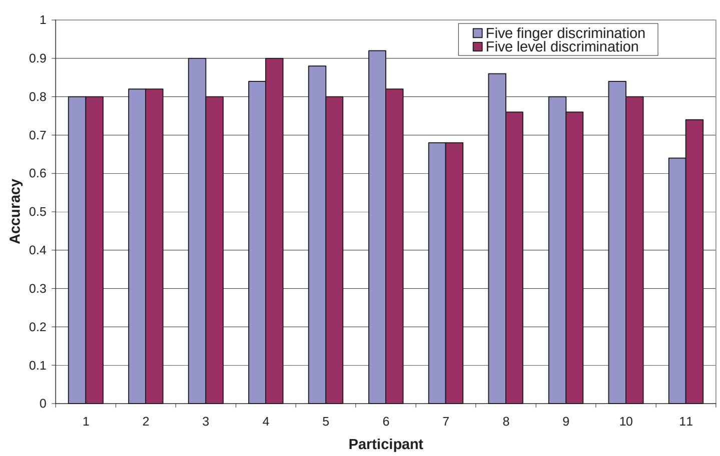

Figure 1: Results from five finger discrimination and five level discrimination tests.

FEASABILITY OF PROCESSING GAIT DATA WITHOUT ACCESS TO ALL REQUIRED MARKER LOCATIONS

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AIM: Clinical gait laboratories typically use a specific marker set for acquiring gait data. When patients are wearing orthoses, such as ankle-foot or knee orthoses, some marker locations are covered by the orthosis. A common solution is to position markers over the orthosis approximately in correspondence with the underlying correct position, therefore introducing errors not accounted for in the data analysis and in the comparison with normative data. In this study we propose a method to overcome such problems.
METHODS: The gait of three subjects wearing a sleeve-type knee orthosis extending to mid shank and thigh was acquired with a marker set based on the CAST method [1], using an 8-camera Vicon 512 system. Those markers required by the Plug-in-Gait model located on body parts covered by the orthosis (lateral femoral condyle and lateral thigh and shank markers), were not attached to the subjects' skin. However, their trajectory was generated by combining data from the anatomical landmark calibration and acquired gait trials. Specifically, the lateral femoral condyle was calibrated and the lateral thigh and shank marker trajectories were generated from their location in the anatomical reference frame identified with the CAST method. These procedures allowed the resultant data to be compared to the normative data acquired and processed using Plug-in-Gait model.
RESULTS: Selected curves of the knee kinematics and kinetics of the braced leg of the three subjects over the normative data are illustrated below (Figure 1).

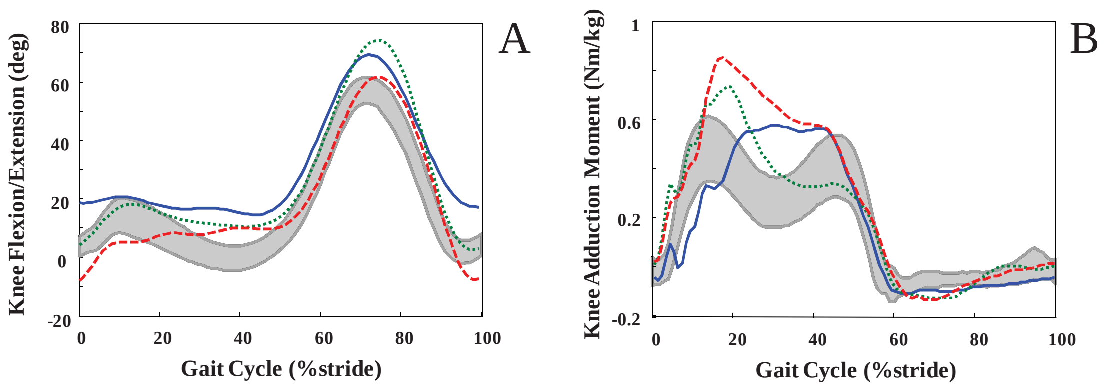

Figure 1: Examples of knee kinematics and kinetics of the three subjects superimposed to the relevant normative data (gray band: ± 1 st. dev.): A) knee flexion angle (deg) and B) knee adduction moment (Nm/kg).
CONCLUSIONS: The study showed that it is possible to compare the joint mechanics of a braced knee to normative data even when the brace does not allow one to position markers in the required marker locations.
REFERENCES: [1] Cappozzo et al., Clinical Biomechanics, 1994.
ACKNOWLEDGMENTS: The authors would like to thank W. Harvey and D. Stamenovic for their inputs and M. Goldsmith for her help.

NEUROMECHANICS OF MOVEMENT DISORDERS FOLLOWING STROKE: THE EXPLICIT-STROKE PROGRAM

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AIM: Improper joint resistance after stroke can be a result of tissue visco-elasticity, muscle activity and neural reflexes. These neuromechanical properties depend on the task instructions and on movement amplitude and velocity. Hence, we propose a combination of robot controlled tests to quantify neuromechanical properties of the wrist joint sensitively over a wide range of operation. Data processing includes basic signal analysis and linear closed-loop system identification techniques. Within the EXplaining PLastICITy after stroke programme, these neuromechanical parameters are assessed longitudinally and repeatedly in a large cohort of patients starting within the first week after stroke.
METHODS: EMG controlled manipulations of the wrist joint were performed using a single axis (haptic) manipulator (Wristalyzer®, MOOG FCS). This allows for unambiguous external conditions and objective results regardless of the observer. Nine tests were performed involving active and relaxed tasks, these being: 1) passive ROM, 2) active ROM, 3) stiffness in rest, 4) maximal voluntary contraction, 5) force to failure, 6) spinal reflex time 7) Ashworth, 8) wrist stiffness under constant contraction and 9) wide band (WB) multi-sine force perturbations. Outcome measures comprise passive and active muscle-tendon visco-elasticity, spinal reflex time and reflex gain (modulation).
RESULTS: The protocol was successfully applied to chronic stroke patients and controls, Fig.1. High stiffness (1A) and lack of gain adaptation (1B) discriminated patients from controls.
CONCLUSION: The proposed approach allowed for discrimination between underlying tissue, active muscular and reflexive neuromechanical properties. Repeated measurements in a longitudinal study design will allow for discrimination between primary and secondary factors. In combination with fMRI and TMS, neuromechanics will help us towards understanding plasticity after stroke.
ACKNOWLEDGEMENT: R. van Ee, D.C. Balderas Silva, control software development.

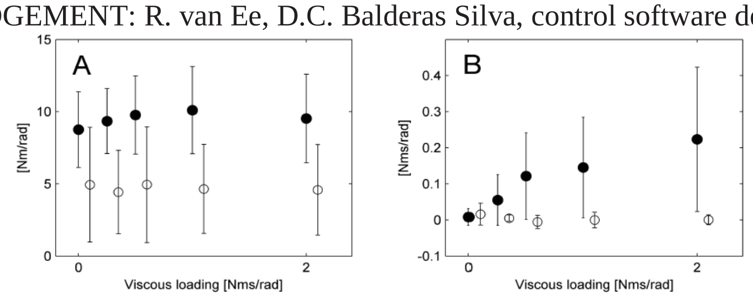

Figure 1: Results for multi-sine force perturbations (WB) while subjects were instructed to hold position while being subjected to force perturbations show a clear distinction between patients (o) and controls (●) on an activation and neural level. A. Controls show high stiffness due to active (co-) contraction; B. Patients do not increase reflex amplitude when assisted by an increase in virtual viscous loading (modulation).

ELECTRICAL ACTIVITY OF CERVICAL MUSCLES AND RANGE OF MOVEMENT OF CERVICAL COLUMN

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AIM: To verify the electrical activity of cervical muscles and the range of movement of cervical column and the relationship between them, in individuals with and without temporomandibular disorder (TMD).
METHOD: 53 volunteers, 24 with TMD and 29 without TMD, both genders, age between 18 and 32 years took part in the study. The TMD was diagnosed through Research Diagnostic Criteria for Temporomandibular Disorder (RDC/TMD). The electromyograghy of Sternocleidomastoideus and Upper Trapezius muscles was carried out bilaterally with a sample frequency of 2 KHz and band-pass filter of 10-1000Hz. The measures of flexion and extension range of movement were acquired through a fleximeter. The comparison between groups were analyzed by Mann-Whitney test and the correlation between the variables were tested by Pearson and Spearman tests, with 5% of significance level.
RESULTS: There were no differences in the range of cervical movements between groups (Table 1). The means of RMS values at rest in the TMD group were higher than in the control group, with statistical difference in the right SCM and Trapezius muscles (Table 2). There were no significant correlations between electrical activity levels and range of movements in the cervical column.
CONCLUSION: TMD individuals presented changes in the electrical activity in the cervical muscles, but it did not affect the range of cervical movements. However, the levels of electrical activity at rest were low and the ranges of movement were next to the normal degrees and no significant correlations between these variables were found.

Table 1: Degrees of range of cervical movement in TMD and Control groups

Range of movement	TMD group		CONTROL group		p
	Mean ± SD		Mean ± SD		
Extension	71,88	±12,70	75,31	±7,90	0,3467
Flexion	62,92	±13,57	57,52	±8,95	0,1758
Right lateral tilt	45,69	±7,53	43,83	±5,05	0,3515
Left Lateral tilt	46,69	±7,03	45,69	±5,56	0,5954

Table 2 – Mean and Standard-Deviation of RMS values (µV) of Cervical Muscles Activity at rest in TMD and Control groups

MUSCLES	TMD group		CONTROL group		p
	Mean ± SD		Mean ± SD		
Sternocleidomastoideus right	5,15	±1,35	4,26	±1,01	0,0130*
Sternocleidomastoideus left	4,87	±1,58	4,59	±1,35	0,6295
Trapezius right	11,22	±11,62	6,06	±4,68	0,0334*
Trapezius left	9,88	±9,60	7,25	±5,46	0,0335

U MANN-WHITNEY test (*Significance level p< 0,05)

HEAD POSTURE AND MUSCLE ELECTRICAL ACTIVITY IN SUBJECTS WITH AND WITHOUT TEMPOROMANDIBULAR DISORDERS

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AIM: To determine the head posture and electrical activity of masticatory and cervical muscles, as well as the relationship between these variables in individuals with and without TMD, at rest situation and maximum intercuspal jaw position.
METHOD: 60 subjects aged between 18 and 35 years of both genders were classified by using the instrument Diagnostic Criteria for Research on Temporomandibular Disorders (RDC / TMD) in asymptomatic (30) and TMD (30). The craniocervical posture was verified by photogrammetry and electrical activity of the masseter, anterior temporalis, upper trapezius and sternocleidomastoid, by electromyography, at rest situation and maximum intercuspal jaw position.
RESULTS: There was no difference in the head posture between the groups. The electromyographic examination showed that only the left temporal muscle was significantly more active at rest in TMD patients (p= 0,0147), with no difference in maximum intercuspal position between the groups. It was observed significant correlations only in the study group: positive between the right sternocleidomastoid muscle and the angle of the upper cervical spine at rest (p= 0,0420) and maximal intercuspal position (p = 0,0363) and, negative between the right and left masseter and the same angle in the maximum intercuspal (p= 0,0440; p= 0,0430, respectively).
CONCLUSION: Based on the results, it can not be said that there is an association between head posture and TMD, as well as between the activity of masticatory and cervical muscles and TMD. However, the head extension seems to be a postural compensatory mechanism to maintain the strength of the masticatory muscles in these individuals.

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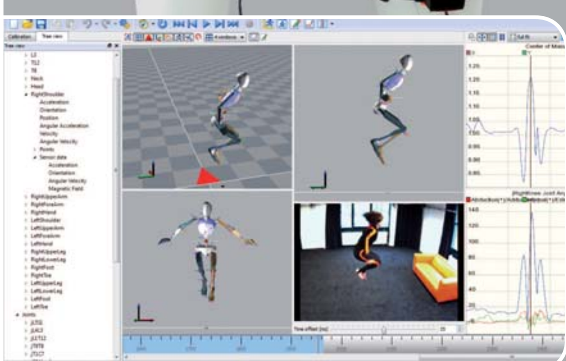

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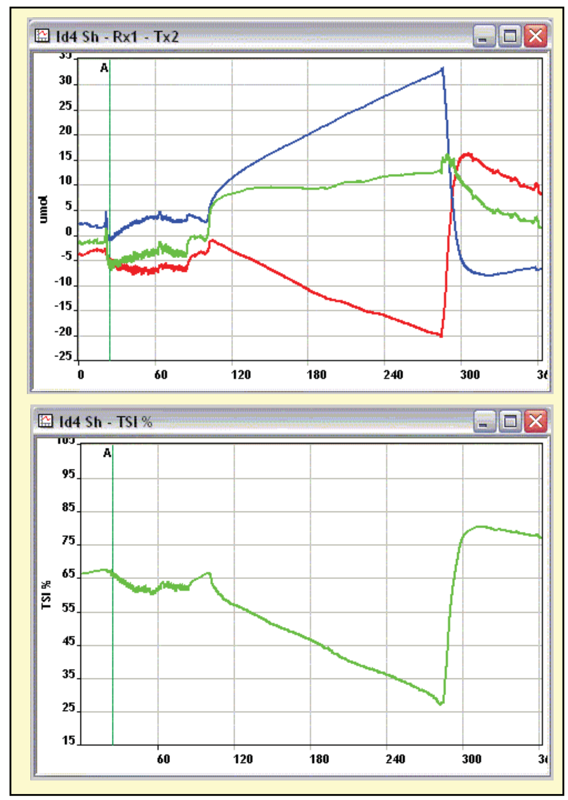

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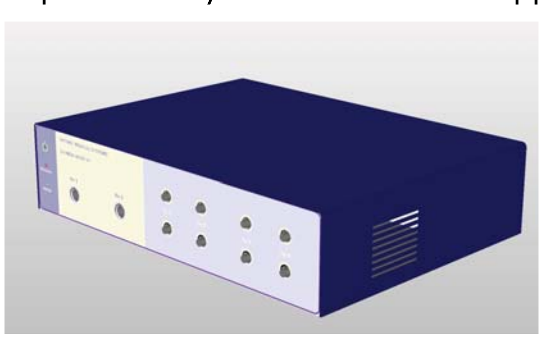

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