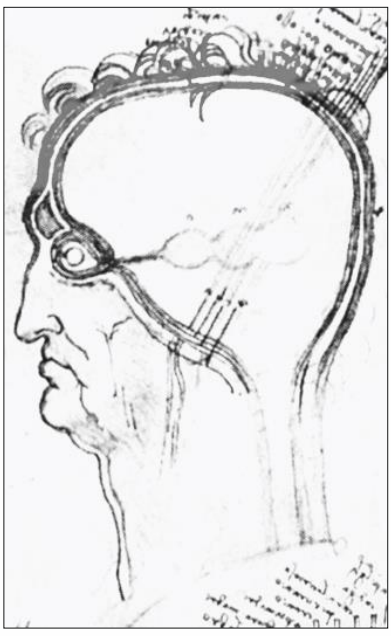
International Scientific Conference

# MOTOR CONTROL 2024

From Theory To Applications

## Book of abstracts



18-20 September, 2024

Wisła, Poland

*International Scientific Conference*

# *Motor Control 2024*

*From Theory To Applications*

**18th – 20th September 2024**
**Wisła, Poland**

# *BOOK OF ABSTRACTS*

**Edited by Kajetan Słomka and Grzegorz Juras**

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*Poster presentations:*

# Poster Presentations

# Kinematic Equivalence, Neuromuscular Difference: Exploring Hand Dominance in Response to Perturbation

**Anna Akbaş[1,2], Mariusz Furmanek[1,2,3], Mathew Yarossi[1], Eugene Tunik[1]**

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**Introduction:** Hand dominance plays a key role in motor performance, with the dominant hand (DH) generally exhibiting smoother and more efficient movements. However, recent theories propose that the non-dominant hand (NDH) may offer greater stability and control, especially under perturbations like unexpected force or visual changes.

**Objectives:** This study examines reach-to-grasp coordination differences between DH and NDH under visual and mechanical perturbations. We explore (1) kinematic and EMG differences, (2) compensatory responses, and (3) the distinct effects of visual versus mechanical perturbations on each hand's performance.

**Methods:** Thirteen right-handed participants performed 160 reach-to-grasp trials with each hand in a virtual environment under three conditions: control (no perturbation), visual (object displacement), and mechanical (6.36 N force to the forearm), in random order. Perturbations were introduced 300 ms after movement onset. Kinematic data were recorded using infrared markers on the thumb, index finger, and wrist, and EMG from eight arm muscles: FDI, EI, APB, EPB, BB, TB, AD, and PD. A t-test compared DH and NDH in control condition, and a two-way repeated measures ANOVA assessed differences in responses to perturbations, examining the effects of hand and perturbation type.

**Results:** Kinematic analyses revealed no significant differences between hands in transport- or grasp-related features. However, EMG data showed significantly higher muscle activity in the DH, particularly in the AD in early and in FDI, APB and AD in late phase of movement. Under perturbation conditions, both hands exhibited equivalent kinematic performance, but EMG responses differed: the DH showed increased activation in the AD, APB, and EPB muscles, while the NDH exhibited greater activation of the TB muscle.

**Conclusions:** Despite similar kinematic performance, DH and NDH used different motor control strategies. DH relied on thumb muscles (APB, EPB) and AD for fine control, especially under perturbations, while NDH engaged proximal muscles like TB to stabilize. These findings highlight the role of hand dominance in neural control during reach-to-grasp tasks.

# Mapping hand function in rare developmental disorders

**Andrea Berencsi[1] and Tibor Vámos[1,2]**
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**Introduction:** Hand dysfunction affects participation in school and work, daily activities and quality of life, and is therefore a priority area for special educational needs. Rare disordesrs affect five person or less out of 10 000 and are less studied in the field in motor control and functon research. The present study aimed to map motor, sensory and functional features of hand function in rare neurodevelopmental disorders.
**Methods:** The study included persons with Williams syndrome (WS, n=17), Beckwith-Wiedemann syndrome (BWS, n=3), Prader-Willi syndrome (PWS, n=4) and Duchenne muscular dystrophy (DMD, n=6) who gave informed consent to participate. The assessment of hand function was performed in the domains of somatosensation (Nottingham Sensory Assessment-NSA, stereognosis test), motor (muscle strength measurement, fine movements, Muscular Dystrophy Functional Rating Scale) and activities of daily living (Jebsen-Taylor Hand Function Test-JTHFT, Abilhand questionnaire) and participation.
**Results:** Impairment of hand function was prevalent in the WS, PWS and DMD groups reflected in both motor domains and activities of daily living, which, in addition to common features, showed different patterns across syndromes. In the assessment of somatosensory modality, the WS group showed involvement in the areas of tactile localization and proprioception, while the DMD group showed involvement in tactile localization in two subjects. In the DMD group, the assessment of proprioception was hampered by motor dysfunction, while in PWS, the need for syndrome-specific adaptation of questionnaires was raised. In the BWS group, there was no functional deviation from the age-matched sample.
**Clonclusion:** The results have drawn syndrome-specific features of hand function. They also confirmed findings that emphasise the involvement of hand function in everyday activities. The inclusion of additional participants in small groups is necessary to increase the reliability of the study. The practical experience gained from these studies also raises the need for the development and use of syndrome-specific survey procedures.

# Postural control training with Nintendo Wii in Down syndrome

**Andrea Berencsi[1,3], Evelyn Ardai[1,3], Gabriella Papp Gabriella[1,3], Tibor Vámos[1,2,3]**

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**Introduction:** The motor profile of individuals born with Down syndrome (DS) may be characterized by reduced muscle strength and tone, as well as joint hyperflexibility that all may affect postural control and balance. Increasingly popular Virtual Reality systems such as the Nintendo Wii offer the opportunity to test and develop motor skills in DS individuals. We aimed to investigate functional abilities and learning capacity of basic motor skills for postural control and visual vertical perception in DS individuals.

**Methods:** Participants with DS (n=18) and typical developmental (TD=7) between 18 and 30 years of age took part in the study. All participants underwent pre- and posttests by the Berg Functional Balance Scale - BERG, 30 seconds sit up and plank tests, Five times sit to stand test - FTSST, Timed up and go test - TUG and visual vertical (VV) perception using Bucket test. DS participants were then randomly divided into two groups: test (DS Wii=9) and control (DS control=9). After the condition assessment, members of the DS Wii and TD group participated in 8 sessions of balance training with the Nintendo Wii, during which they worked with two selected games, Sliding Penguin and Goalkeeper.

**Results:** The baseline performance of DS and TD participants differs in the basic motor skills required for postural control. During the Wii training, the DS Wii and TD groups' game scores show significant performance improvements in both the Sliding Penguin (DS Wii: $p<0.001$; TD: $p<0.002$) and the Goalkeeper (DS Wiip<0.002; TD: $p<0.01$) games between training subtests 1 and 8. The DS Wii group's pre- and post-Wii training scores indicate a significant change in motor skills related to postural control (BERG: $p<0.01$; TUG: $p<0.001$; PLANK: $p<0.003$; FIGHT: $p<0.001$; FTSST: $p<0.002$). No significant change was measured between the pre- and post-Wii training mean scores for visual vertical perception (VV) in either group.

**Conclusion:** Both gaming performance and functional status of the participants improved after Wii training showing that Wii may be an efficient tool for balance training in DS. The study will continue with the inclusion of additional participants.

# Frequency-domain correlation analysis of upper limb muscle activity in wheelchair fencers

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The study includes a correlation analysis of EMG signals of upper limb muscle activity in wheelchair fencers. Wavelet transform analysis was used to examine the biosignals. The recorded EMG signals were subjected to time-frequency transformations. The scalograms were determined using the continuous wavelet transform. Based on the analysis, time-frequency coherence maps were extracted to determine validation in the frequency bands: 2-16 Hz, 17-30 Hz, and 31-60 Hz. The study participants were 16 wheelchair fencers, members of the Polish Paralympic Team, in two disability categories: 7 in category A and 9 in category B. Coherence was calculated for frequencies up to 60 Hz. The analysis revealed the individual time-dependent coherence between two signals for different frequencies during the work cycle of the antagonist muscles of the arm (biceps/triceps) and forearm (flexor/extensor carpi radialis). A significant difference in alpha coherence (2-16 Hz) occurred in the group of forearm muscles. Its peaks were observed during the fencing action cycle. Some differences in gamma coherence were also found in the EMG signals of the forearm muscles. The results confirm the neuromuscular conduction, where alpha coherence reflects the reticulospinal tract responsible for the excitation of the distal muscles of the wrist and hand, while gamma coherence results from cortical signals. It is related to efferent conduction and reflects corticomuscular coupling. Frequency domain coherence analysis determines the strength of intermuscular synchronization, allowing a comprehensive investigation of the neural mechanisms underlying motor recovery. It maps separate neural pathways for arm and hand control.

# The effect of dual task on kinetic and kinematic of parkinsonian gait: a statistical parametric mapping analysis compared to healthy control

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**Background.** Parkinson's disease (PD) is a progressive neurodegenerative disease that includes several motor symptoms such as abnormal walking patterns, requiring a cognitive effort. Moreover, performing a cognitive task during walking decreases the quality of motor performance. **Objective.** To analyze kinetic and kinematic parameters in single and dual task walking in people with PD compared to a healthy control (HC). **Methods**. Inclusion criteria were: 30-75 years old, ability to walk unaided, without impairments affecting walking, and no cognitive impairment (Mini-Mental State Examination <24). Only idiopathic PD were enrolled. Motion Capture system was used to record kinetic and kinematic data. Subjects walked a 10-meter path at a comfortable speed under two conditions: spontaneous walking (single task) and counting backward (dual task), randomly. We collected 15-25 trials per condition. Intra-group (single vs. dual task) and inter-group (same task condition) comparisons were performed regarding spatio-temporal parameters, range of motion (ROM) of the lower limb's joints, and Ground Reaction Forces (GRFs). Statistical analysis was performed using t-tests or Statistical Parametric Mapping (SPM)
**Results**. PD (n=12) compared to HC (n=6) showed statistically significant reduction in cadence (step/min), step and stride length (m), and swing time (s) with increase in step and stance time (s), double limb support (s) and stride width (m), across all trials. In dual-task conditions compared to single tasks, PD had less knee flexion from toe-off to initial swing, less plantar flexion near toe-off, and statistically significant increased dorsiflexion during push-off compared to HC during dual-task conditions. Considering GRFs, PD showed significantly lower braking and propulsive forces in both conditions compared to HC, with further reductions between single and dual tasks only for the PD group.
**Conclusion**. PD affects the kinetics and kinematics of walking. Several differences were observed compared to healthy subjects in single and dual-task conditions. The dual-task seems to modify motor performance only in the PD group.

# Jerk analysis of gait in persons with incomplete spinal cord injury: a study about the effect of hybrid arm and leg cycling

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Walking ability can sometimes be improved in people with incomplete spinal cord injuries (iSCI). For them, the well-selected therapy is crucial. During the hybrid Functional Electrical Stimulation (FES) cycling, the paralyzed legs' muscles are stimulated with electrical impulses to cycle, while the patient performs voluntary arm cranking simultaneously. This method may help to reorganize the remaining neural connections of iSCI persons.

We investigated the gait ability of two iSCI patients. They involved in hybrid FES training program twice a week for 12 weeks. Both were able to walk with crutches before the program, but their gait was unsteady. The patients' walking ability was measured before and after the program. From the kinematic data, the jerk of the foot as an endpoint, and the decomposition of endpoint jerk into components, related to time derivatives of angular changes, was investigated. We calculated the jerk of the motion from the first 3 derivatives of the knee and ankle joint. The Total endpoint Jerk (TJ) was distributed into 4 Jerk Components (JC). The 1st JC depends mostly on the angular velocity, the 2nd on the angular acceleration and these are independent of the angular jerk. The 3rd JC depends on the angular jerk and the 4th, depends on all three. For the first patient TJ increased slightly in both legs during the program. In JC the 3rd component was the dominant both before and after the program, but a small decrease in this dominance was observed in both legs. For the second patient, a difference was found between the two legs. TJ was higher for the right then for the left foot. After the program, TJ of the right foot decreased, and for the left increased. Thus, the jerk values became more similar in the two legs. In JC the 3rd component increased for the right leg and decreased for the left leg but kept the dominance. Both patient's walking speed increased.

The distribution of the JCs is specific for the movement task. This specific distribution didn't change after the program. The more balanced jerk values comparing the two legs, may reflect improvement in the walking patterns of the individual patients, besides higher walking speed.

# Gait stability in older adults after tripping simulated perturbation - project assumptions and preliminary results

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The literature indicates that locomotor adaptability in general, and anticipatory and reactive adaptation in particular, remain largely intact in the elderly. Therefore, experiencing near-fall situations in a safe environment can facilitate reactive balance control in everyday life situations, and thus increase fall prevention. Various methods have been used to generate perturbations in the laboratory. Terrestrial systems can have a high similarity to real-world conditions, however, induced perturbations tend to occur in a fixed location and may result in a loss of 'unpredictability'.

Therefore, our aim is to create a protocol that allows to study many gait cycles, application of multiple perturbations in an unpredictable way for the subject and the assessment of gait stability after perturbation, which as much as possible resembles a trip in natural conditions.

The proposed prototype allows to work during walking on a mechanical treadmill. It consists of a braking element, which block the movement of foot during swing phase. The handle allows free plantar/dorsal flexion and external/internal foot rotation. The braking module is synchronized with the beginning of the swing phase by footswitch sensors. The perturbation delay time and duration are controlled by a microcontroller.

To measure gait stability we used margin of stability (MoS) in anteroposterior direction calculated as the difference between the anterior boundary of the base of support and the extrapolated XCoM, by using a reduced kinematic model. Kinematic data during walking was recorded with Innovision Motion Systems using six cameras and Zebris FDM-T treadmill (f=100Hz).

The results for the four consecutive baseline right steps during touch down:

| $P_{Tro}$ *(m)* | $V_{Tro}$ (m/s) | $V_{C7}$(m/s) | *XCoM (m)* | *toe projection (m)* | *MoS (m)* |
|---|---|---|---|---|---|
| 0,177 | 0,006 | 0,078 | 0,2520 | 0,34 | 0,088 |
| 0,176 | 0,06 | -0,042 | 0,2411 | 0,337 | 0,096 |
| 0,168 | 0,042 | 0,024 | 0,2403 | 0,332 | 0,092 |
| 0,17 | 0,048 | 0,006 | 0,2405 | 0,324 | 0,084 |

Results of the MoS during unperturb gait are similar for these reported in previous research. Next step will be to verify whether our system will be capable to register all kinematic data after perturbation and then to adopt various selection of perturbation parameters.

# Range of trunk motion in post-stroke patients could be enlarged by visual biofeedback-based training

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The stroke incidence has significantly increased over the last decade worldwide. The majority of patients remain with a minor or major functional motor and/or sensory deficit, the degree of which can be corrected by timely and qualified rehabilitation aimed at the restoration of lost neurological functions, such as an independent movement. In stroke patients with hemiparesis, an asymmetric trunk position is often characterized by unilateral tilt or limited mobility on one side. Recent studies have shown that additional sensory information improves rehabilitation when added to standard motor skills training. In our study, we implemented targeted sensory intervention aimed at modulating trunk symmetry and improving trunk mobility. We used an original methodology, which consists of a special chair with a built-in force platform, a portable control unit, a height-adjustable monitor, software and a set of training tasks.

A total of 9 patients (7 men, 2 women, mean age: 62.2 y) underwent an additional intervention which consisted of visually guided trunk tilt in a sitting position during hospitalization at the University hospital. The intervention lasted 8 days (15-20 min/day). A set of eight tasks included voluntary trunk tilts using visual feedback about trunk position, involuntary tilts induced by vibration of the trunk muscles and their combination. Before and after the intervention, we evaluated postural stability while sitting with eyes open and closed and functional limits of stability, i.e., maximum volitional trunk tilts in the medio-lateral direction. After completing the intervention, the functional limits of stability increased from 5% to 54% on the paretic side. Restoring the balance function and symmetry of the trunk, even if partial, is crucial for improving the ability and independence of stroke patients to perform daily activities. Additional sensory information can positively influence neural mechanisms and thus contribute to the improvement of motor performance and support the effective re-acquisition of lost motor skills.

Supported by APVV-20-0420 and VEGA 2/0080/22.

# The motor learning effects of combining an external attentional focus and task-relevant autonomy

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Research spanning several decades has explored methods to effectively enhance motor learning. Theoretical explanations suggest, and recent empirical evidence has shown, that combining autonomy-supported (i.e., self-controlled) practice conditions with an external focus of attention may benefit motor learning outcomes. However, not all studies have consistently provided evidence supporting these benefits. One explanation for the mixed results is the provision of autonomy over task-irrelevant information. Studies have demonstrated that autonomy-supported conditions utilizing task-relevant information can produce greater benefits compared to task-irrelevant information.

The present experiment aimed to investigate the combined effects of an external attentional focus and task-relevant autonomy on the motor learning of a standing korfball shooting task. A total of 110 PE graduate students (41 females and 69 males, average age = 22.53) participated in the study. Participants were randomly assigned to one of four practice groups: external focus (EXT), internal focus (INT), autonomous (AS), and autonomous-external (AS-EXT). They performed 50 trials (5 sets of 10 repetitions) over 3 consecutive days, totaling 150 trials. A mixed ANOVA was conducted to assess the impact of different instructional groups on motor learning during the test and acquisition phases. The results indicated significant effects for both test and acquisition phases, as well as a significant interaction between instructional groups and test phases.

The findings suggest that practicing with an external focus of attention results in greater motor learning compared to an internal focus of attention. However, the study did not find evidence that autonomous conditions provide an additional motor learning benefit when combined with an external focus. These results highlight the importance of an external focus of attention in motor learning while questioning the assumed benefits of combining autonomy support with specific attentional instructions.

# Assessment of the metric properties of sensor-derived measurements during the execution of the part III of the MDS-UPDRS in persons with Parkinson Disease: the INERTIAL Study protocol

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Parkinson's disease (PD) is a neurodegenerative disorder that results in various motor symptoms such as gait dysfunctions, rigidity, bradykinesia, and tremors. Currently, diagnosis, staging, and clinical grading primarily rely on clinical assessments. The MDS-UPDRS is the most objective and standardized evaluation tool, but it has limitations, including variability in scores between different raters and within the same rater. Inertial Measurement Units (IMUs) offer a simple and objective way to measure movement and digitize clinical outcomes, improving communication among rehabilitation professionals. Given their potential to support the diagnosis and monitoring of PD, it is crucial to explore the benefits of integrating these technological tools into clinical practice. This study aims to evaluate the reliability and validity of measurements recorded using a set of IMUs during MDS-UPDRS Section III tasks in individuals with PD. At least 50 participants will be recruited from the General Rehabilitation Organizational Structure of the University of Florence, located within the IRCCS Fondazione Don Gnocchi (FDG) in Florence, Italy. Participants will wear the inertial sensors and perform tasks from MDS-UPDRS Section III. At T0, the first assessor will apply the sensors, and an expert clinician will assign corresponding scores as the participants perform the tasks. At T1, another examiner will place the sensors and record the data. At T2, the first examiner will repeat the assessments, including sensor placement and data recording. IMUs have emerged as versatile and essential tools in human movement analysis, with the potential to enhance the quality of care for PD patients. They could play a crucial role in improving clinical assessments, refining rehabilitation strategies, and ultimately contributing to a better overall quality of life. Conducting studies to explore their effectiveness in clinical

settings is vital for advancing our understanding of their capabilities and optimizing their use in patient care.

# The Impact of Visual Disturbances on Human Body Balance Strategies: Trend Analysis of COP Displacement

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**Introduction:** Time and frequency domain analyses enable comprehensive assessment of balance. Maintaining stable posture requires continuous correction of the center of pressure (COP) and center of mass (COM), necessitating detection of momentary, non-cyclic changes. This study aims to develop a method using innovative trend change analysis to assess vertical body position under conflicting sensory stimuli. Trend change analysis will allow to determine the number of posture corrections, the time and distance between these corrections, and the speed of COP movement between them, revealing the impact of visual disturbances or different sceneries on posture.
**Methods:** The study included 28 healthy individuals (13 females, 15 males, mean age = 21 years, SD = 1.3 years). Measurements were conducted in real-life environments with eyes open and closed, as well as in virtual reality. Virtual reality scenarios included open and closed space environments oscillating at frequencies of 0.7 Hz and 1.4 Hz. Analysis involved COP displacements during the middle 30 seconds of each test. Mean COP velocity and movement range in the AP direction were calculated. Trend analysis involved computing values such as trend change index (TCI), TCI_dT, TCI_dS, and TCI_dV. TCI represents the total number of trend changes segmented into periods of 0–0.2 s, 0.2–0.5 s, and 0.5–1 s.
**Results:** TCI values remain stable regardless of measurement conditions, suggesting a required number of trend changes for stable posture. At 1.4 Hz, there's an increase in TCI in the 0.2-0.5 s period and a decrease in the 0.5-1 s period, correlating with body movement following the scenery. Changes in TCI_dT and TCI_dS values indicate whether changes in velocity are due to the change in the length of individual COP leaps, the time of these leaps, or both. A simultaneous increase in TCI_dS and a decrease in TCI_dT could indicate much longer COP leaps in a shorter time, potentially leading to destabilization and falls.
**Conclusion:** Trend change analysis complements standard time and frequency domain analyses. Examining values based on TCI provides additional insights into factors influencing standard parameters like correction frequency or correction intervals.

# Isokinetic testing as a safe tool in the assessment of muscle strength in children: role in normal motor development

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**Introduction:** Muscle strength is a fundamental aspect of children's motor development, affecting their motor skills and overall health. Classical methods of assessing muscle strength can be less precise or difficult to apply to the pediatric population. Isokinetic testing represents a modern and promising approach, offering safe and accurate measurements of muscle function in children.

**Objective:** The aim of this study is to review and evaluate the effectiveness and safety of isokinetic testing in measuring muscle strength in children and to analyse its impact on normal motor development.

**Methods:** Data from dozens of scientific studies on the use of isokinetics in the assessment of muscle strength in children (n = 1200) were analysed. Measurements were made using isokinetic dynamometers in different age groups and for different muscle groups. Relationships were also investigated between measurement results and indicators of motor development and children's physical activity levels.

**Results:** The literature review showed that isokinetic testing is effective and well tolerated by children, providing accurate and reliable data on muscle strength. The results of isokinetic measurements correlate with children's level of motor development and physical activity. Research confirms that regular monitoring of muscle strength using isokinetics can help identify potential developmental disorders and support therapeutic intervention programmes.

**Conclusions:** Isokinetic testing is a valuable tool in the assessment of muscle strength in children, offering safe and accurate measurements. The use of this technology in clinical practice has the potential to significantly improve motor development assessment strategies and allow early detection of abnormalities, leading to better health and physical outcomes for children.

# Biomechanical Investigation of Gait and Myoelectric Activity in ALS Patients

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**Introduction:** Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease that progressively impairs voluntary movement. By the time symptoms emerge and patients receive a diagnosis, most of their motor units have likely degenerated, suggesting limited therapeutic success for treatments aimed at slowing or halting disease progression. **Purpose**: The project focuses on understanding early-stage ALS by examining muscle firing patterns and alterations in participants with ALS and age-, sex, and race-matched controls. We are investigating how early motor unit losses are concealed by compensatory changes in muscle firing and kinematic patterns using a combination of high-density surface electromyography (HD-sEMG), conventional surface electromyography (sEMG) and motion capture techniques. **Methods:** Gait dynamics and muscle activation patterns (timing and amplitude) are measured during locomotion. HD-sEMG is recorded during a 30% maximal voluntary isometric contraction of the tibialis anterior (TA). The multi-channel EMG signals are processed to show the discharge of a single motor unit, location of the action potential across the 64-electrode grid and the motor unit firing rate. This can be analyzed with the measured torque to understand motor neuron excitability. Machine learning techniques will be used to define EMG features predictive of disease progression. **Results**: Firing patterns are presented for a healthy participant during a 30% MVC trial. Pattern of activation were assessed using a measure of algorithm accuracy, discharge rate at recruitment and derecruitment and the coefficient of variation in firing rates. Figure 1 represents the sorted instantaneous discharge rate of different motor units and shows how, as force input increases, motor units with high activation threshold are recruited. **Discussion**: To date, we have collected HD-sEMG on healthy individuals and demonstrated consistent motor unit recruitment and compensation. This suggests robustness in assessing motor unit properties. These insights into baseline motor function can inform analyses in ALS patients, providing a reference for identifying early compensatory changes in motor unit dynamics.

# Can Transcutaneous Electrical Nerve Stimulation improve walking and fatigue in persons with Multiple Sclerosis?

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**Background + Objective:** Persons with multiple sclerosis (pwMS) often show walking difficulties and an increased sense of fatigue. Recent studies suggest that transcutaneous electrical nerve stimulation (TENS) may increase walking capacity and decrease fatigue in pwMS. This study investigates the effect of TENS with and without concurrent exercises of the quadriceps femoris on walking distance and fatigue in pwMS.

**Method:** 74 persons with MS were evaluated before, directly after and two weeks after 12 treatment sessions with either sham stimulation, sham+exercises, TENS or TENS+exercises of the quadriceps femoris bilaterally. Each evaluation session consisted of completing questionnaires about fatigue (FSS and MFIS), walking limitations (MSWS-12), assessment of the 6-minute walk test (6-MWT), 30-second chair stand test (30-CST) and force measurements of the quadriceps femoris.

**Results:** The scores of the FSS, MFIS, MSWS-12, 30-CST and MVCs and force steadiness of the quadriceps femoris improved over time ($p < .05$), regardless of intervention. Notably, the TENS group walked 25 m further on the 6-MWT directly after intervention ($p < .05$) and 22 m further 2 weeks after intervention ($p < .05$). In contrast, there were no significant changes over time in the other groups. Furthermore, 78% of the pwMS that received TENS in rest showed a clinically meaningful improvement (improvement > 21.6 m) in walking distance post-intervention.

**Conclusions:** Participants demonstrated improvements over time on most outcome measures, irrespective of the intervention, underscoring the importance of an appropriate control group. Notably, TENS improved walking distance. Future studies should investigate neurophysiological mechanisms of TENS and the differences between responders and non-responders before TENS could be widely used as a rehabilitation tool.

# Walking speed regulation in females in advanced pregnancy

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**Introduction:** The pattern of self-selected speed during walking in late pregnancy seems to be somewhat similar to that of older people, and the percentage of falls in both groups is estimated to be similar. There are no reports presenting the walking pattern of gravid women at a speed higher than their preferred one. Therefore, the purpose of this study was to assess the effect of movement speed on the dynamic stability of women in advanced pregnancy.

**Methods:** 10 women in the third trimester of pregnancy (~36 weeks) who met the inclusion criteria were enrolled in the study. The mean age was 30.61 ± 3.49 years ($\bar{x}$± SD), and the mean body mass and height were 73.79 ± 8.99 kg, 1.67 ± 0.04 m, respectively. At first the anthropometric measures were taken. Then the gait test was performed. The registration involved over-ground walking trials along a 12-m walkway at a natural (self-selected) speed (N variant) followed by trials performed at speed higher than natural (F variant). The analysis was performed using a 5-camera video-based (120 Hz) motion analysis system (Vicon 250; Oxford Metrics Ltd., UK). Based on 10 gait cycles, spatio-temporal gait variables and sagittal plane angles in the ankle, knee and hip joints were determined from each measurement session. Additionally the size of the base of support was considered.

**Results:** Analyzing the spatio-temporal structure of gait, it was noted that the change in locomotion speed significantly affected all the variables. The average walking speed in N variant was 1.32 m/s, while in F variant it increased to 1.56 m/s. There was also a significant increase in the stride length (by 11 cm) and frequency (by 12 steps/min). The consequence of the increase in speed was also a significantly shorter time of double and single support. No significant changes in the size of the base of support were noted. In turn, the analysis of the sagittal plane mobility of the lower limb joints revealed significantly larger mobility of the hip (~4°) in faster walking. Also in this case the maximum flexion of the hip joint increased significantly. Thus, while increases in stride length, cadence, and angular motion are normally linked to increases in walking speed, we observed a differential effect of speed on the ranges of angular motion in pregnant women: only increases in the hip joint, not the knee or ankle joints.

**Conclusions:** The results revealed significant impact of the speed on all the spatio-temporal variables during walking in advanced pregnancy excluding area of support. The hip flexion occurred to be an important element in the strategy of providing higher walking speed.

# Comparison of Dominant and Non-Dominant Hand Reach-to-Grasp Kinematics in Haptic-Free Virtual Reality: Implications for Motor Control and Rehabilitation

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Reach-to-grasp movements are fundamental motor actions that involve the coordinated reach of the hand toward an object and the simultaneous shaping of the hand to grasp the object. Understanding the kinematic differences in these movements between the dominant (DH) and non-dominant (NDH) hands can provide insights into motor control and rehabilitation strategies for motor impairments. Thus, we aim to compare the reach-to-grasp movement execution between the DH and NDH in immersive, haptic-free virtual reality.

13 (5F) healthy right-handed adults (25.7 ±7.97 years old) took part in this study after signing the IRB informed consent. Subjects were instructed to reach-grasp-lift with their DH and NDH to three differently sized: Small - 3.6 cm, Medium - 5.4 cm, Large - 7.2 cm rectangular objects located at three different distances: Near - 24 cm, Middle - 30 cm, Far - 36 cm from the starting position in a random order. Differences between the DH and NDH were evaluated by comparing the movement kinematics of the reach and grasp components. A 2x3x3 rmANOVA revealed many similarities in movement kinematics between DH and NDH. Specifically, movement time (MT), peak aperture (PA), time to peak aperture (TPA), time to peak transport velocity (TPTV), and closure time (CT) were not significantly different between the two hands (all p's > 0.05). As hypothesized, MT was proportionally longer for objects placed further; PA was scaled to object sizes, and peak transport velocity (PTV) was scaled to object distances for both DH and NDH. Surprisingly, PTV showed faster movements when reach-to-grasp action was performed by a non-dominant hand, $F_{(1, 12)} = 7.88$, $p = 0.015$.

Our results suggest that both limbs possess comparable functional capabilities in executing reach-to-grasp movements, however, the NDH exhibit larger PTV when movement is performed in virtual reality. Further research is needed to explore the underlying mechanisms contributing to observed differences in PTV and determine how these findings can improve motor rehabilitation.

# Keeping Stable in Standing, Tuning the Corrective Ground Reaction Force to Center of Mass Kinematics

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EMG activity and ankle moments following balance perturbations have been shown to be well coordinated to prior center of mass position and velocity. Since control of stability is ultimately reflected in the ground reaction force, we hypothesized that a relationship exists between the corrective horizontal ground reaction force (GRF) and preceding center of mass position (COM) and velocity (VCOM) in unperturbed standing. Such a relationship would reflect the lumped effects of intrinsic mechanical impedance and feedback control. Additionally, due to varying stability demands and the impact of different standing configurations on the body's intrinsic mechanical properties, active feedback control may differ across different standing postures. Thus, we also hypothesized that feedback gains in such a relationship would increase with increasing stability demands, and delay might also differ in varying postures. To test our hypotheses, we fitted a linear regression model to human experimental data obtained from 6 standing postures, standing: with feet together, unipedally, in tandem stance, in three step postures (with body mass on the front leg, between the feet, on the rear leg). The GRF could be well-reconstructed from COM and VCOM with $R^2$ ranging from 0.89 to 0.97. Contrary to our hypothesis, there were no significant differences in gains of COM (-721~-767 N/m) and VCOM (-226~257 Ns/m) between tasks. However, the delay was significantly longer in normal standing (261 ms) than in all other postures (181 ~ 209 ms). In conclusion, our results supported that COM and VCOM information are used to generate corrective ground reaction force to maintain stability, and this control can be represented by a simple linear regression model. Furthermore, feedback control parameters are similar across postures, while high-demanding postures have significantly faster responses compared to normal standing.

# Age-Related Insights into Motor Control using the One-Target Advantage Phenomenon

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The One-Target Advantage (OTA) is a concept where Movement Time (MT) to a target in a single-target aiming task is shorter compared to the identical target in a sequential two-target task. The OTA paradigm has been used to better understand motor planning and execution processes in various populations; however, age-related differences are not well understood. Given successful sequential movements are needed for many activities of daily living, the primary objective was to explore if and how age influences the OTA.

Twelve older (60-78years) and twelve younger adults (19-35years) performed one (1T) and two target (2T) aiming tasks on a touchscreen. Three-dimensional movement displacement data was collected using an optical position measurement system with a sampling rate of 300Hz. A 2 Group by 2 Target type (1T, 2T) mixed ANOVA was used to analyze the first movement segment; t-tests for the second segment. Significant interactions were analyzed using Bonferroni corrected t-tests.

A significant main effect of Task type for MT ($F_{1,22}$=5.62, p=0.027, $\eta_p^2$=0.203) indicated both younger and older adults took significantly longer to perform the first movement segment in the 2T compared to the 1T task. Target type also significantly influenced both constant error ($F_{1,22}$=5.97, p=0.023, $\eta_p^2$=0.213), and peak velocity (PV)1 ($F_{1,22}$=9.12, p=0.006, $\eta_p^2$=0.293). Relative to the 2T task, both groups overshot the target centre when performing the 1T task. A significant Group by Task type interaction ($F_{1,22}$= 5.30, p=0.031, $\eta_p^2$=0.194) indicated that only the younger group reached a higher PV in the 1T versus 2T task. Task type also had a significant effect on Time After PV (TAPV; $F_{1,22}$=4.37, p=0.048, $\eta_p^2$=0.166), such that both groups had a longer TAPV in the 2T compared to the 1T task.

In summary, older and younger adults both exhibited the predicted OTA. In contrast to the younger adults, older adults did not modulate PV in the 1T task. However, both groups did use a longer TAPV in the 2T task. These results contribute to our understanding of aging and motor control by demonstrating that older adults successfully perform multitarget tasks by adjusting their motor control strategies.

# Fear of heights affects postural control during the virtual height exposure

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The virtual reality (VR) allows individuals to experience variety of environments that are not easily accessible in real life or that they might avoid due to fear or safety constraints, such as heights. To examine how the fear of falling influences balance control independently of aging and pathology, healthy individuals are exposed to various postural threats, representing natural stressors. The most common postural threat is exposure to height by the surface elevation on which individuals stand. Our study was aimed to examine postural and psychophysiological responses to virtual height exposure in 42 young individuals with varying intensity of fear of heights. A virtual open-air elevator was used for height simulation and the measurements were carried out during stance on an unstable surface at ground level and at virtual heights of 20 m and 40 m. The height exposure elicited a complex, robust, and reliable psychophysiological response with significant changes in emotional state, sympathetic activity, and postural control, which were enhanced in individuals with a fear of heights. Individuals with higher fear showed a rigid and more stiffened posture characterized by smaller magnitude and simultaneously increased velocity of body sway. Our findings highlight different postural strategies between individuals with and without fear of heights and underline thigh association between psychophysiological markers of perceived stress with balance control. For the assessment of postural stability in stressful environments, such as height exposure (both real and virtual), it is important to take into account the currently experienced fear and anxiety that can significantly contribute to resulting postural stability and may have more significant implications in populations with a fear of falling.
Supported by VEGA 2/0080/22 and APVV-20-0420.

# Neural modeling of the result in women's 400m hurdles running

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**Background:** the 400m hurdles run is one of the most demanding (motorically and technically) athletic competitions. The final result consists of a great many factors related to the parameters of the athlete, technical preparation, motor preparation and strategy.
**Purpose:** The main purpose of the study was to evaluate neural models performing the task of predicting the outcome in the women's 400m dash calculated using four different groups of variables (basic, temporal, spatial and strategic).
**Material:** The analysis used detailed data on the 42 final runs of major world (Olympic Games and World Championships) and continental (European Championships) events held between 1978 and 2022. A total of 327 individual runs of 149 female hurdlers (54.54 seconds) were included. The variables used in the study were divided into 4 groups: (1) basic (body parameters, WPT, PB400m, among others), (2) temporal (times of the partials of the run expressed in absolute and percentage values), (3) spatial (number of steps and variables characterizing the “rhythm” of the steps) and (4) strategic (running track and stage positions).
**Method:** Multilayer percoptron (MLP) and radial basis function (RBF) networks were used to determine neural models. All models were validated using cross-validation. The study used Root Mean Squared Error (RMSE) as a quality criterion.
**Results:** The analysis showed that both methods had similar RMSE errors for each set of variables. The MLP network calculated dal time parameters (RMSE=0.175 s) turned out to be the most accurate neural model. The MLP network for basic parameters had the largest error (RMSE=0.925). For models based on spatial data, both methods generated similar errors (for MLP - RMSE=0.448 s; for RBF - RMSE=0.450 s). The situation was similar for strategic variables (for MLP - RMSE=0.850 s; for RBF - RMSE=0.800 s).
**Conclusions:** The data prove that the most useful (lowest estimation error) elements in evaluating the strategy of women's 400m hurdles running at the highest level are related to temporal (“split times”) and spatial (“stride pattern”) variables. Somatic structure, level of technical and motor preparation and choice of running track are important, however, their importance can often be unpredictable.

# Combined aerobic-strength exercise improves trunk dynamics in patients with Parkinson´s disease

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**Introduction:** Engaging in consistent physical activity was shown to improve motor functions such as gait, balance, and coordination, which are often impaired in patients with Parkinson's disease (PD). Currently, levodopa is the most effective symptomatic treatment for PD, primarily addressing its motor symptoms. Despite its efficacy, long-term use of levodopa can lead to complications such as motor fluctuations and dyskinesia, necessitating potential adjunct interventions. Therefore, it is necessary to focus on effects of such interventions in both stages, with and without antiparkinsonian pharmacotherapy.
**Methods:** Fifteen PD patients (11 M, 65.5±6.8 yrs) underwent supervised 4-month aerobic/strength training, individualized according to participants' physical fitness. Training consisted of 2x 1 h of strength/aerobic and 1x 1 h of aerobic coordination training weekly. Postural control was assessed before and after the 4-month training. Measurement was conducted under the "ON" state (with antiparkinsonian medication), and the "OFF" state (refraining from antiparkinsonian medication for 12-24 h before measurement). Balance was measured by 2 accelerometric sensors attached to the upper and lower trunk in 4 conditions: standing on a firm/foam surface with eyes open/closed. For each trial and each sensor location, 4 variables were calculated: sway area, sway path, mean frequency, sway jerkiness. The Wilcoxon paired test was used to evaluate the effect of training.
**Results and conclusion:** Aerobic/strength training improved trunk stability, particularly in the OFF state. Improvement of trunk dynamics was manifested by reduced mean frequency, sway path, and sway jerkiness while standing on foam with eyes open and closed. Similar results were obtained during the stance on a firm support surface. Our results showed that regular exercise enhanced dynamic trunk stability in PD patients, addressing one of the core motor dysfunctions associated with the disease. Particularly in the state when the patients are "off" medication, these improvements mitigate the risk of fall and ameliorate overall mobility. Consequently,

patients can experience better performance of daily activities, contributing to greater independence.

Supported by VEGA 2/0080/22, VEGA 2/0076/22, APVV-20-0420, APVV-20-0466.

# Let's dance - Postural Control in Ballroom Dance Couples: Differences Between Professional and Amateur Couples

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**Background**: Ballroom dance is a unique sport where male and female partners, as a couple, maintain a handhold position and move as one throughout the dances. When they enter the dance floor, they create unity. It is crucial to assess dancers as a couple rather than as individual partners. The aim of the study was to identify changes in postural sway among ballroom dancers, comparing the female dancer, the male dancer, and the dance couple in a specific swing dance position.
**Methods**: A total of seven international standard ballroom dance couples voluntarily participated in the study, along with fourteen students specializing in dance who had practiced ballroom dancing for 3 months. Postural sway was evaluated using two force plates. The experimental procedure comprised a standard dance position. The assumption of the assessed position was preceded by a dance phase, after which the participants were instructed to freeze on the force plates and hold the position for 30 seconds. The trials were repeated twice. A two-way analysis of variance was used to determine the role of individual partners forming the dance couple in postural control.
**Results**: Both female and male professional dancers exhibited significantly higher values of raCOP and rms COP compared to the control group ($p < 0.05$). No differences were recorded when analyzing them as a couple. The opposite situation was observed for sample entropy. No significant differences were registered between individual dancers, but the professional dance couple exhibited higher sample entropy compared to the amateur couples ($p < 0.05$). In the group of professional dancers, significantly higher values of raCOP and rmsCOP were observed between the male dance partner and the dance couple ($p < 0.05$). However, a significantly higher value of sample entropy was recorded for the dance couple compared to the individual partners ($p < 0.05$). In the control group, no differences in postural sway and sample entropy were observed between the dance couple and the individual partners.
**Conclusion**: Ballroom dance training has a significant impact on postural sway characteristics. The female dance partner plays a stabilizing role for the dance couple, reducing their postural sway. The professional dance couple exhibits less regularity in the COP signal, which may indicate greater automation compared to the amateur couple.

# Head orientation modifies the contribution of vestibular information to trunk control during walking

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Theme: Postural control and locomotion

Electrical vestibular stimulation (EVS), which produces illusions of self-movement, is widely used to probe the vestibular system. Previously, we found EVS induced phasic, vertebral level specific paraspinal muscle activity during walking. This indicates that vestibulospinal reflexes contribute to trunk stabilization during walking. Head orientation changes the direction of the EVS induced illusion (e.g., in the frontal plane when facing forward and in the sagittal plane when the head is turned 90 degrees to the side) and modifies the vestibulospinal reflexes during standing. We investigated whether and how head orientation changes the contribution of vestibular information to paraspinal muscle activity during walking. Sixteen participants walked on a treadmill for 8 minutes at 78 steps/min and 2.8 km/h, in four conditions defined by the presence of EVS and head orientation (facing forward or leftward). Bipolar electromyography (EMG) was recorded bilaterally from the paraspinal muscles from the C7 to L4 vertebral level. Coherence, gain and delay between EMG and EVS were characterized. Significant EVS-EMG coherence in the paraspinal muscles was observed at heel strikes in both head orientations. The leftward head orientation significantly decreased the EVS-EMG coherence and gain compared to walking with head forward. This overall decrease may be explained by the effectiveness of passive stabilizing control in the sagittal plane during walking. However, the decrease in coherence was only significant at the left-lower and the right-upper vertebral levels around left heel strikes. This is possibly because the head yaw rotation pivot is located posterior to the origin of vestibular reference frame. Therefore, a leftward head orientation will induce an offset of the vestibular axis to the left relative to the trunk reference frame. Consequently, motion to the left encoded by the vestibular signal would be smaller than motion to the right, causing an asymmetric response to vestibular afference. This study confirmed the contribution of vestibular information in trunk stabilization while highlighting that this contribution is impacted by head orientation during walking.

# Upweighting lumbar proprioception through prolonged electrical vestibular stimulation: an application of sensory reweighting

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Postural control relies on multisensory information, which is integrated based on the relative reliability of the sources, in a process known as 'sensory reweighting'. Low-back pain (LBP) reduces the lumbar proprioceptive contribution to postural control. As such, LBP patients may increase dependence on other modalities, such as vestibular signals. Attenuated response to prolonged electrical vestibular stimulation (EVS), which induces illusions of self-movement, has been reported. This could temporally up-weight the lumbar proprioception. Here, we investigated reweighting between vestibular information and lumbar proprioception during sitting in healthy participants. Ten participants sat upright on a stool placed on a force plate, with their hands hanging freely at the sides and their feet on the ground with a 90-degree knee flexion. Trunk kinematics were measured with markers on the back at the T6 level. Unilateral muscle vibration (80 Hz) on the left paraspinal muscle at the L2 level was applied, with each vibration round consisting of ten times 5-second vibrations with 10-second rest intervals. Vibrations were applied at 0 (MV1), 10 (MV2) and 20 (MV3) minutes during EVS, and 5 minutes before (Pre-MV) and after EVS (Post-MV). Stochastic EVS (2 to 25 Hz) was applied for entire 30 minutes. The weight of the vestibular signal was quantified as the gain between EVS and horizontal ground reaction force (GRF) in the medio-lateral direction. Although the EVS-GRF gain showed no decrease over 30 mintues, trunk roll in Post-MV (0.28 ± 0.17 degrees) increased compared to Pre-MV (0.25 ± 0.17 degrees, $p = 0.15$). The presence of EVS significantly increased trunk roll (Pre-MV vs MV3, $p = 0.04$). In sum, prolonged EVS temporarily up-weights the lumbar proprioception in healthy participants. However no post-stimulation effect was found after 5 minutes of rest. These findings suggest that prolonged EVS could potentially be applied in the treatment for LBP.

# Tools for assessing spasticity by detecting Tonic Stretch Reflex Threshold (TSRT): a systematic review with meta-analysis

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**Introduction:** Spasticity is one of the most common and disabling symptoms that follow a first motor neuron injury and afflicts over twelve million people worldwide. The framing of tone disorders within the referent control theory allows for a parameterization of symptom spasticity, which, in turn, could represent a valid standard of measurement. Aim of this study is to evaluate the overall metric properties of spasticity measurement tools detecting the Tonic Stretch Reflex Threshold (TSRT).

**Methods:** Search filters have been built following the COSMIN guidelines for systematic reviews. The search was conducted on MEDLINE, CINAHL, Scopus, Web of Science and EMBASE on April 20, 2023. All studies that reported data on reliability, validity, and/or responsiveness of TSRT measurement tools performed on adult subjects with central nervous system disorders and spasticity were selected. Subsequently, two reviewers independently selected the studies, conducted the methodological quality assessment, and extracted the results. All the meta-analyses used a "random-effect model".

**Results:** 9776 titles were retrieved from the databases, reduced to 9575 after removing of duplicates. 9003 studies were excluded after screening of titles and abstracts and 572 full-text articles were screened for eligibility, of which 7 were ultimately included. Further 5 pre-screened articles from other source have been included in the review. Among these only 1 study investigated intra-rater reliability while just 3 reported data about the inter-rater. Data on convergent validity have been found in 9 articles. Only 1 study directly reported data about both internal and external responsiveness. We extract data on internal responsiveness from two other studies.

**Discussion:** Reliability studies proved to be very few and had significant measurement errors. Results regarding validity were heterogeneous perhaps due to a lack of reliability of both the TSRT measure and comparators. Data regarding responsiveness are poor, with only 1 study reporting an analysis of external responsiveness. The TSRT measure seems to be promising for the assessment of spasticity but needs further studies to better detect metric properties.

# Comparison of locomotion speed during different cognitive and motor tasks in subjects with Parkinson's Disease

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Individuals with Parkinson's disease (PD) have reduced walking speed. However, the relationship between walking speed and different task conditions remains unclear. This study aims to investigate walking speed in single and dual task conditions in individuals with PD. This cross-sectional study analyzed initial data from a controlled clinical trial developed at the “Reference Center for Aging and Movement” (CREM) in Brazil. A total of 15 individuals, 67.1±8.1 years old, 9 men, recruited through community advertisements and diagnosed with PD with a score of 1 to 3 on the Hoehn and Yahr (1967) scale. Participants walked in a straight line, with time measured in the central ten meters to calculate walking speed in meters per second (m/s). Conditions evaluated in the test: 1) participants walked at self-selected speed (SWSS) in standard conditions, without additional tasks; 2) dual motor-cognitive task involving arithmetic reasoning; and 3) dual motor-cognitive task of writing a message on the cell phone. OpenSim was used to collect biomechanical data, while statistical analyzes were performed using JASP. The average values were: SWSS (4.10±1.12 km/h), arithmetic (3.71±0.98 km/h) and cell phone (2.82±1.11 km/h). SWSS showed differences in relation to arithmetic ($p=0.043$) and cell phone ($p<0.001$), while arithmetic also differed from cell phone ($p=0.005$). The activity of typing on a cell phone combines fine motor skills, stabilization of the shoulder girdle and relative visual deprivation, involving multiple tasks of sensorimotor integration and cognitive demands. Gait speed is significantly affected by these demands, and other motor parameters of locomotion still need to be investigated.

# Exploring the Impact of Augmented Sensory Feedback on Movement Performance in Younger and Older Adults Using the One-Target Advantage Paradigm

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**Introduction:** Ongoing technological advancements offer new opportunities to use augmented sensory cues, like sound and vibration, to facilitate daily movements. The present experiment used the One Target Advantage (OTA) paradigm to explore how augmented sensory feedback, specifically vibrotactile and auditory stimuli, may influence movement control. The OTA posits that Movement Time (MT) to reach a target is typically shorter compared to when the same reach is followed by a movement to a second target. To date, age-related changes in OTA and the impact of augmented feedback remain underexplored.
**Methods:** Eleven older adults (60-78years-old) and twelve younger adults (19-35years-old) used a custom stylus to perform goal-directed reaching movements to one (OT) or two targets (TT) displayed on a touchscreen. Participants completed 6 blocks of 20 trials in a counterbalanced order. Each block consisted of either OT or TT movements and one of the three sensory conditions (No Feedback-NF, Auditory-A, VibroTactile-VT). Brief augmented feedback (200ms) was provided upon touching the first target. The stylus position was recorded using 3D motion capture at a sampling rate of 300Hz. Data were analyzed using a mixed 2 Group by 2 Target task (OT, TT) and 3 Sensory conditions (NF, A, VT) ANOVA. Significant effects were further analyzed using Bonferroni-corrected t-tests.
**Results:** There was a significant interaction between Target task and Sensory condition for Reaction Time ($F_{2,44}$=4.10, $p<0.023$, $\eta_p^2$=.157), with shorter RTs in the TT task with VT feedback. A main effect of Sensory condition for both MT1 ($F_{2,44}$=5.26, $p<.009$, $\eta_p^2$=.193) and MT2 $F_{2,42}$=5.74, $p<.006$, $\eta_p^2$=.215) showed that vibrotactile feedback led to shorter MTs. A significant effect for Sensory condition for Time after peak velocity of the second movement, $F_{2,42}$=9.01, $p<0.001$, $\eta_p^2$ =0.300, indicated participants performed fastest in the vibrotactile condition.
**Conclusion:** Taken together, vibrotactile feedback led to more efficient and equally accurate movements, particularly in the two-target task. Integrating novel technology into everyday tools may offer an opportunity to enhance daily tasks by utilizing different types of augmented feedback.

# Verbal feedback and the effectiveness of learning complex motor skill

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The effectiveness of motor learning is very important already at an early stage of sports training. The effectiveness of motor learning depends, among other things, on providing feedback to the learner. Hence, it is important to provide appropriate feedback regarding the source, accuracy, time or frequency of delivery, depending on the complexity of a motor skill and the level of advancement of the learner. Despite numerous studies, there is a lack of conclusive evidence to confirm the effectiveness of motor learning when using verbal feedback in gymnastic sports, especially at an early stage of sports training.

The aim of the study was to determine the influence of verbal feedback on the effectiveness of learning a pike jump on a trampoline in children aged 6-8.

Forty-five children (n = 45) aged 6-8 from the sports acrobatics section participated in the study (126.2 cm ± 5.6 cm; 23.3 kg ± 1.5 kg; 6.9 ± 0.9 y). The experiment, experts' evaluation and evaluation of the movement structure based on a biomechanical analysis were applied as research methods. In the experiment, the participants learned how to perform a pike jump on a trampoline. They were randomly divided into three groups: BCC (n = 15) – they received verbal feedback on errors concerning the whole motor skill performance, BSK (n = 15) – they received verbal feedback on errors and how to correct them in the whole motor skill, and BKE (n = 15) – they received verbal feedback on errors that occurred in key elements.

As a result of the study, three key elements of the pike jump on a trampoline were identified: the launching posture (UCR), the multiplication posture (UCM), and the concluding posture (UCL). Evaluation of the pike jump technique was performed three times (in the pre-test, post-test and retention test). In the post-test, the highest mean score was observed in the BKE group, and the lowest in the BSK group ($p < 0.05$). In the retention test, despite a decrease in the mean value of the scores, the highest score was maintained in the BKE group, and the lowest in the BCC group ($p > 0.05$).

Limiting feedback to errors that occurred in key elements only is most effective in learning the pike jump on a trampoline.

# Integrating Virtual Reality with mirror therapy, NIRS and EEG: Advancement in Neurorehabilitation for stroke recovery

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Globally, stroke is the major cause of disability and its prevalence will rise 21.3% by 2030. Most of the disability reported from stroke survivors are upper-limb motor dysfunction and they are unable to perform their routine activities. Advancements in rehabilitation provide aid to do normal life activities to the stroke survivors but still, some gaps need to be filled. Translation from physical therapy to advanced neurorehabilitation techniques results in fast motor task recovery. The objective of this study is to find the literature on Virtual reality (VR) with the integration of mirror therapy, Near-infrared spectroscopy (NIRS), and Electroencephalography (EEG). Furthermore, filters for preprocessing, targeted subjects, and clinical assessment measures were also analyzed. To do this, articles indexed in Web of Science and Google Scholar are analyzed. The inclusion criteria for literature are the subject having a stroke, upper/lower limb dysfunction, and articles published from 2020 to 2024 while the exclusion criteria are, articles of virtual reality with NIRS/EEG other than stroke diseases and review articles. It is found that the contribution of VR and EEG is 53% in 2023 which is the highest among other techniques. Most Activities used in virtual reality scenes are grasp, grip, pinch, gross arm movement, shoulder up and down movements, spread shoulder in-out, rotating shoulder, and elbow in-out. To increase interest in the subject with rehabilitation, some VR games are also highlighted e.g. Beat Saber, a stack wooden blocks Basketball game. The most frequently used functional outcomes for clinical assessment are the Fugl-Meyer Assessment, Box and Block Test, Functional Independence Measure, Independent Component Analysis (ICA), Brunnstrom recovery stages (BRS), Modified Ashworth Scale (MAS), T-test, Wavelet analysis and Analysis of variance ANOVA (mostly use). In most of the randomized control trial, statistical significance was set to $p<0.05$ and young people. Moreover, the Future direction in rehabilitation will be autonomous assessment and upgradation of virtual exercises with time, the status of recovery, and the implementation of machine learning algorithms for data preprocessing and filtration to achieve a more accurate assessment and fast recovery.

# The relationship between the torque generated in the ankle joint and the body balance parameters of the limits of stability test

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The aim of the study was to investigate whether the torque generated during dorsiflexion and plantarflexion of the ankle joint under isokinetic conditions influences the results of the "Limits of Stability" (LOS) test. The functional LOS test measures volitional control of the center of gravity (COG). Using computerized dynamic posturography, it is possible to objectively measure the displacement of the center of pressure (COP). This parameter is used to examine neurological and biomechanical mechanisms of posture control. Isokinetic contraction refers to muscle contraction accompanying limb movements at a constant speed around the joint. The speed of movement is maintained at a constant level using a special dynamometer. The resistance of the dynamometer matches the muscle force applied throughout the range of motion. Isokinetic dynamometry has been identified as a reliable tool for measuring peak torque in the ankle joint (Aydog et al., 2004). A total of 36 adult professional dancers from the Śląsk Song and Dance Ensemble were examined (18 women and 18 men). The functional "Limits of Stability" test was conducted on a posturographic platform (AMTI, Accugate). The subject stood on the platform and, upon signal, tilted the body maximally forward without lifting the heels off the ground. The average of three measurements was taken for analysis. The ankle joint torque for dorsiflexion and plantarflexion was measured using the Biodex System 4 isokinetic chair. Both the right and left limbs were tested at a speed of 30°/s. To eliminate the effect of gravity on torque, each limb was weighed by the Biodex system, and the data were corrected by the software. Spearman's rank correlation showed a positive correlation between the mean value of COP position in the AP direction in the local reference system relative to the lateral malleolus for phase 3 and the average torque for the left ankle joint (plantarflexion) ($r = 0.422$, $p \leq 0.05$). Spearman's rank correlation also showed a positive correlation between the mean value of COP position in the AP direction in the local reference system relative to the lateral malleolus for phase 3 and the average torque for the right ankle joint (plantarflexion) ($r = 0.428$, $p \leq 0.05$). Additionally, Spearman's rank correlation revealed a positive correlation between the COP range in phase 3 (Max-Min) and the average peak torque for the left ankle joint during dorsiflexion ($r = 0.405$, $p \leq 0.05$).

# The assessment of upper limb proprioception with use of the Laser-Pointer Assisted Angle Reproduction Test (LP-ART)

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**Background:** Proprioception is an important somatosensory sub-system that affects movement. Proprioceptive deficits are associated with musculoskeletal disorders but remain a challenge to quantify, particularly at the shoulder.
**Purpose:** This pilot study aimed to assess upper limb proprioception with the use of the Laser-Pointer Assisted Angle Reproduction Test (LP-ART) in sport dancers.
Material and methods: The study included a group of 18 sport dancers (among them eight advanced) and 21 sports inactive people as the control group. The assessment of upper limb proprioception was made with the use of the Laser-Pointer Assisted Angle Reproduction Test (LP-ART) as described by Balke et al. in 2011.
**Results and conclusions:** The results allowed conclusions to be drawn. 1) Sport dance training may improve the level of upper limb proprioception. 2) In all groups the results were better in the right upper limb than in the left one, but not significantly. 3) The effect of upper limb injuries on proprioception was observed in the subgroup consisting of beginning dancers and the control group but not in the subgroup consisting of advanced dancers. 4) The Laser-Pointer Assisted Angle Reproduction Test (LP-ART) is an adequate tool for the measurement of upper limb proprioception.
Keywords: assessment, dance-sport, joint position sense, proprioception, laser-pointer test, upper limb.

# Unveiling the Mechanism of Action Instrument Assisted Soft Tissue Mobilization

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Instrument Assisted Soft Tissue Mobilization (IASTM) is an intervention using special tools to treat skin, fascia, muscles, and tendons. Studies suggest it improves mobility and decreases pain. IASTM is often referred to as a neuro-mobilization technique, however research on how IASTM affects the neuromuscular system is limited. **PURPOSE:** To test whether and how IASTM affects lower extremity corticospinal excitability (CSE) in healthy adults as measured by response in H-reflex amplitude. **METHODS:** 30 healthy adults volunteered to participate after signed written consent. Participants were randomly assigned to one of three equal groups: control (C), sham (S), and IASTM. The IASTM group received 4-min treatment to the triceps surae. The S group received an intervention using the same strokes as IASTM, but with a wooden tongue depressor and pressure less than 1N. The C group received no intervention. Maximal motor response ($M_{max}$) was recorded from the right soleus muscle by stimulating the tibial nerve to elicit an H-reflex as a percentage of $M_{max}$. Ten baseline H-reflexes were recorded. Following intervention, the same procedure was performed immediately after and at, 1-, 5-, 10-, 15- and 30- min intervals. Data was normalized to respective baseline measurements. A 3 x 6 repeated measure ANOVA with factors of Group and Time was used to evaluate the effects of the IASTM on H-reflex amplitude. **RESULTS:** Analysis revealed a significant main effect of Time ($F_{(5, 45)} = 8.65$, $p = .0001$), and significant interaction of Group x Time ($F_{(10, 90)} = 3.49$, $p = .0006$). Post-hoc analysis revealed significant effects between C vs. IASTM and S vs. IASTM ($p$'s $< 0.001$) indicating that IASTM decreases H-Reflex amplitude at 15 and 30- min post intervention.

**CONCLUSION**: Our results demonstrate an inhibitory effect of IASTM on CSE suggesting IASTM may result in inhibition of the neuro-muscular system.

# What happens during an unintentional force drift? Using sample entropy to explore force matching

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The mechanism of unintentional force drift is well-reported in the literature. However, previous analyses with various scenarios primarily focused on overall characteristics, such as the magnitude or direction of force changes under different task constraints. In this project, we investigated the variability and complexity of unintentional force drift observed during a force-matching task. Twelve healthy adult participants took part in the study, performing a force matching task that involved producing 20% of the maximal voluntary contraction (MVC) force using their index and ring fingers of one hand (task hand) and then reproducing this force magnitude with the same fingers of the other hand (match hand) after a specified time (4, 8 and 15 s). Participants received visual feedback of the produced force throughout all measurements (feedback condition) or only during the initial 5 s of the matching trial (no-feedback condition). After the removal of visual feedback, a drop in the force magnitude was observed across all participants and all conditions. The participants were unaware of these changes and reported accurate task performance. The force drifts were analyzed using basic indices such as standard deviation and root mean square, as well as with the sample entropy method. Entropy analysis was highly sensitive during unintentional force drifts with significant differences based on hand dominance, feedback and duration of matching time. The obtained results suggest that participants could change their focus of attention during the task execution to find another source of information that could help them in performing the task. This may offer an additional interpretation of the unintentional force drift phenomenon.

# Reaction and Motor Times of Special Unit Operator Candidates at Different Stages of Military Training

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**Background:** At the forefront of national security are the Special Forces Units (SFU), which are responsible for carrying out the most demanding and risky operations. SFU are mainly characterized by elite soldiers, high level of physical preparation, commitment, creativity, adaptation to changing combat conditions. They must react quickly and make flawless decisions.
**The purpose** is to determine the reaction time and motor time of a candidate for Special Forces Unit Operator. In addition, changes in the studied abilities at different stages of military training will be analyzed.
**Material:** The study included 70 Polish SFU candidates at various stages of recruitment at the age of 30. The candidates were divided into two groups: Selection (n=38), SAC (n=32). The Selection group consists of those who completed the mountain. Those who passed all stages of selection and completed the Special Activities Course (SAC) belong to the SAC group.
**Methods:** Computerized tests of the Test2Drive system were used to assess psychomotor abilities. Two psychomotor tests were used: (1) SIRT (Simple Reaction Time Test) - a test measuring the speed of simple reaction; (2) CHORT (Choice Reaction Time Test) - the measurement assessed the speed and adequacy of the response in a complex situation.
**Results:** The Selection group had the shortest average response time, at 346.68 ms. The SAC group had a reaction time of 352.78 ms. As for the motor time in the SIRT test, it can be considered that the results ranked at a very similar level (Selection - 162.1 ms; SAC - 161.56 ms). Analyzing the times obtained in the CHORT test, a similar trend is noted. The selection group recorded a lower reaction time (687.45 ms) than the SAC group (703.47 ms). A similar trend was observed for motor time in this test (Selection - 182.79 ms; SAC - 184.75 ms). No statistically significant difference was shown for any parameter.
**Conclusions:** The analysis showed that the soldiers are characterized by very good reaction times and motor skills in the tests conducted. A regularity is also noted, the times obtained by candidates after the selection are better than those after the special activities course.

# Relationships between unintentional finger force drifts and surface texture

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Numerous studies over 20+ years have shown that people unintentionally and consistently decrease the amount of force they exert with their fingers in isometric pressing tasks. This phenomenon has been explained as the product of working memory deficits and/or central tendencies of physical systems toward states with lower potential energy. Force drifts might also be explained on another level by time-dependent interactions between object surfaces and the fingertips: as the fingers stay in contact with a non-porous object, dermal ridges begin to conform to the object's surface, resulting in larger contact areas and, consequently, higher friction. In this context, decreases in force production could co-occur when the fingers have larger contact area, which would mean less normal force is required to produce the tangential forces required to manipulate objects. To investigate this hypothesis, 20 healthy young participants completed a series of finger force tests in which we elicited unintentional force drifts as they pressed against two different surfaces. One surface was a plain glass plate which was expected to yield typical time-varying changes in contact area; the other surface was a glass plate covered in polydimethylsiloxane (PDMS) silicone polymer. Previous studies have shown that fingertips do not exhibit this time-varying interaction on PDMS surfaces. Participants initially received visual feedback on the amount of force they were producing which subsequently froze to induce force drifts. After a predetermined amount of time 2-20 s after visual feedback was frozen, participants were asked to slide their fingers over the surface so that we could measure the coefficient of friction after time-dependent fingertip/surface interactions had occurred. Preliminary analyses indicate that the dynamics of force drifts were affected by the surface, although the longer-term magnitude of force drift was less affected. We will discuss these results and their interactions with the frictional forces observed over the course of these force drifts.

# Evaluating Proprioceptive Acuity: Exploring the Differences between Static and Dynamic Position Reproduction

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**Introduction:** Proprioception plays a crucial role in controlling reaching movements. Current methods assess proprioception in static conditions. This raises concerns about the ecological validity of such protocols, as they fail to evaluate proprioception during movements, where timely information about ongoing actions is essential. This study aimed to investigate proprioceptive acuity in both static and dynamic tasks using joint position reproduction (JPR) test during concentric and eccentric muscle contractions.

**Methods:** Seventeen participants completed Dynamic and Static JPR tasks. A tactile stimulus on the dominant limb's wrist provided position cues. Stimuli were administered at Initial (INI), Intermediate (INT), and Final (FIN) phases of movement. In Dynamic JPR, participants received stimulation during either concentric or eccentric phases while performing flexion and extension movements. After completing the ongoing movement, they reproduced the stimulated position. Static JPR involved similar movements with 5 seconds of stationary posture after the stimulation was delivered. Kinematic data were collected using Sentry (SWHARD Srl, Genova), composed of two wearable IMUs. Angular error (AE) was calculated as the difference between the angular stimulation position and the reproduced position. Movement velocity at stimulus delivery was analysed.

**Results:** Participants showed higher AE in Dynamic vs Static Task. Acuity during eccentric contractions was higher than during concentric contractions. During Dynamic Task, in concentric contraction the proprioceptive acuity was better at FIN than INI and INT phases, and in INT than INI. In eccentric contraction, AE was higher in INT phase than FIN. Kinematic analysis revealed significant correlations between velocity at the time of stimulus and AE, in both contractions.

**Conclusions:** Proprioceptive acuity is influenced by the type of task and muscle contraction. Moreover, different movement phases and kinematic characteristics influence the joint position sense. These findings emphasize the importance of

considering these factors when assessing proprioception to ensure accurate and ecologically valid evaluations.

# The effects of analogy, external, and neutral focus instructions on drop jump performance in inexperienced participants

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**Introduction:** The drop jump (DJ) is an essential exercise for plyometric training, offering various benefits for athletic development. Some research suggests that using attentional instructions can enhance DJ performance, however, less is known about the effects of using analogies during the DJ. This study aimed to assess the effect of analogy (ANA), external (EXT), and neutral focus (NEU) cues on DJ performance in inexperienced participants.

**Methods:** Thirty-seven university students (22 men and 15 women) took part in two DJs from a 30-cm box under three attentional conditions. The testing session consisted of six DJs, with attentional instructions in randomized order. An analysis of variance (ANOVA) with repeated measures was used to evaluate differences in jump height (JH), contact time (CT), flight time (FT), and reactive stretch index (RSI) among the three attentional strategies.

*Results*: Results showed significant differences among cue types for JH ($p = 0.02$), CT ($p = 0.036$), FT ($p = 0.015$), and RSI ($p = 0.028$) comparisons. Bonferroni post hoc analyses revealed that the ANA condition resulted in significantly lower CT ($p = 0.04$) and higher RSI ($p = 0.027$) than the NEU instruction. In addition, EXT resulted in increased JH and FT as compared with ANA ($p \leq 0.05$).

*Conclusions*. These findings indicate that both ANA and EXT had an impact on DJ performance. Applying ANA instructions may lead to a more efficient RSI by shortening CT.

# Relationships between leg stiffness and countermovement jump height during tasks from low to maximal performance level

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**Introduction:** Leg stiffness is a quantitative measure of the elastic properties that determine the ability to accumulate potential elastic energy (PPE) in a compliant tissues. Performing a countermovement before take-off during a vertical jump leads to the rapid extension of musculotendinous groups before contraction. This action accumulates PPE and, consequently, positively impacts jump height. However, during vertical jump performed to a part of maximal height, the countermovement may be performed with a smaller range of motion. With a narrow countermovement, the lower limb extensors may be insufficiently stretched, which will reduce the contribution of PPE to muscle energy balance during concentric action. Therefore, the aim of this study is to identify the relationships between leg stiffness and countermovement jump (CMJ) height during tasks from low to maximal performance level.
**Methods:** The study examined 30 male untrained students. Each participant performed 40 single CMJs. 10 jumps each were made to maximum height ($h_{max}$), 50%$h_{max}$, 25%$h_{max}$ and 75%$h_{max}$ (in this order). Further analysis focused on the 4 jumps of each participant (1 highest and 3 most accurate). Measurements were performed using Kistler force plate and BTS SMART motion analysis system. Leg stiffness was determined as a ratio of changes in ground reaction forces to the respective change in the height of the greater trochanter of the femur. Computations were made separately for the countermovement and take-off phases. CMJ height was determined based on flight time method. A one-way repeated measures ANOVA was used to compare the leg stiffness between CMJs to 25%$h_{max}$, 50%$h_{max}$, 75%$h_{max}$ and $h_{max}$.
**Results:** Increases in the CMJ height (from 25%$h_{max}$ to $h_{max}$) were accompanied by reduced of leg stiffness in the countermovement ($p < 0.001$, $\eta^2 = 0.38$) and take-off ($p < 0.001$, $\eta^2 = 0.50$) phases.
**Conclusion:** A relatively small leg stiffness had a positive effect on CMJ height. The accumulated PPE is a quantity directly proportional to the square of the countermovement depth. Smaller values of leg stiffness cause that the countermovement can be deeper (while maintaining an “optimal” range), which positively affects the accumulated PPE and jump height.

# Analysis of spatio-temporal parameters while sending messages

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The use of mobile phones while performing postural or locomotor tasks is an everyday situation for most people at any stage of life and in a variety of environmental conditions. Sending messages (SMS) while walking is the cause of a significant proportion of accidental injuries.
Conduct a comparative analysis of temporal-spatial parameters during a dual task situation of natural gait and texting.
The study involved 110 healthy young adults between 19 and 30 years. The study was conducted on a Zebris FDM-3 dynanometer platform and consisted of two stages. The subject was asked to walk twice on the measuring platform - in the first stage mimicking their natural gait, and in the second stage they were asked to mimic their gait by writing a text message.
From the results, it was observed that during gait with SMS there was a decrease in stride length, a decrease in stride duration and a decrease in velocity, while there was an increase in step frequency and stride width compared to the spatio-temporal parameters obtained during natural gait. For all parameters analysed, the changes were statistically significant.
From the results obtained, it can be seen that texting during gait disrupts the gait by reducing speed and increasing instability.

# Cadence, stride length, or gait speed? Which are the best determinants of effect of gait training early post stroke?

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**Background:** Partial body weight-supported treadmill gait training (PBWStt) is one of recent solutions for improving gait in patients suffering from hemiparesis after stroke. Purpose. The aim of this work was to assess the effect of PBWStt as the intervention added to the standard rehabilitation program on clinical and kinematic parameters of the patients` gait no later than three months after stroke onset.
**Material and methods:** The study involved 64 patients, of whom 32 additionally underwent the PBWStt. In both groups – the experimental and 32-person comparative group used a standard gait reeducation program. For the effectiveness measurement of the method, clinical scales as well as three-dimensional (3D) gait assessment were used.
**Results:** On the basis of conducted research and statistical analyzes, it was considered that a four-week training with partial weight support on the treadmill in the early post-stroke period as intervention added to the standard gait reeducation program statistically significantly affects the gait efficiency and balance. On the other hand, there was no statistically significant effect of gait speed.
**Conclusion:** Moderate severity of stroke, age over 65 years, right-sided paresis and a longer period of time from the onset of stroke correlated with greater effectiveness of this kind of intervention. It seems that cadence and stride length are better determinants of effect of gait training than gait speed.

# The impact of sleep deprivation and moderate physical activity on the ability to differentiate the strength of the forearm muscles

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**Introduction:** The ability to differentiate the strength of the forearm muscles is important in the utilitarian use of motor skills, e.g. during the activities of soldiers. The aim of the study was to assess changes in the ability to differentiate forearm muscle strength during moderate physical exercise and 36-hour sleep deprivation.
Materials: The research was conducted in three groups of young and healthy men aged 19-26:
• PA+SD group - engaging in physical activity during 36 hours of sleep deprivation (n=12).
• SD group - not engaging in physical activity during 36 hours of sleep deprivation (n=12);
• Control group – not subjected to sleep deprivation and physical activity (n=15).
**Methods:** Maximal handgrip force of dominating hand was measured with dynamometer, afterwards subjects were supposed to press 50% of achieved maximum without the visual control and repeat it 5 times, with information from the assistant of scored result after each attempt. The result of the test was expressed by the difference between expected 50%max and achieved average value of five handgrips. The tests were performed at the beginning of the study (M I), after 24 hours (M II) and after 36 hours (M III).
**Results and conclusion:** The conducted studies showed various changes in maximum strength, but they were not statistically significant in any group. The analysis of the absolute values of the ability to differentiate forearm muscle strength did not reveal statistically significant differences between measurements in individual groups. The analysis of raw values revealed that in an attempt to obtain 50% of the desired value (i.e. 50% of maximum strength), no significant differences were found between the measurements in the PA+SD and Control group. Differences at a statistically significant level were found in the SD group (M I -44.64 N; M II -90.21 N; M III 85.35 N). A correlation was also found: in the PA+SD and Control groups there was an "underestimation", while in the SD group, in measurement III there was a significant "overestimation" of the results.

# AWF Activity – a new mobile application for the assessment of health-enhancing physical activity

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**Material and Methods:** A cross-sectional study was conducted with 265 first-grade health-sciences students aged 19-23 years. The following inclusion criteria were applied: consent to participate in the study (a), daily reporting of data over a period of seven consecutive days (b), the typicality of the studied week of life (c), declared absence of physical or mental impairments during the study period (d). The final study group comprised of 179 participants (110 women, height 166.6 ± 6.3 cm, weight 59.7 ± 7.2 kg, BMI 21.5 ± 2.5 kg/m$^2$ and 69 men, height 181.2 ± 6.0 cm, weight 79.5 ± 10.1 kg, BMI 24.2 ± 2.9 kg/m$^2$). A seven-day monitoring of moderate-intensity aerobic physical activity (MPA), vigorous-intensity aerobic physical activity (VPA), and muscle-strengthening activities (M-SA) was conducted using the AWF Activity mobile application (AWF Katowice 2024). The reliability of the AWF Activity mobile application was assessed using the intraclass correlation coefficient (*ICC*). Subsequently, PA parameters necessary for assessment its compliance with the WHO guidelines (2020) were determined. The percentages of subjects with physical activity compliant with health recommendations were calculated.
**Results:** The reliability of the AWF Activity according to *ICC* was for MPA 0.81 [0.75, 0.85], for VPA 0.80 [0.75, 0.84], for S-MA 0.58 [0.48, 0.66]. The average weekly volume of MPA was 384.1 ± 286.5 min, VPA was 211.9 ± 193.9 min. The mean frequency of undertaking M-SA was 2.6 ± 1.4 times a week. Habitual PA is at the health-recommended level in 50.3% of the subjects. The percentage of those meeting the recommendation is significantly ($\chi^2 = 8.17$, $p = .004$, $V = 0.21$) higher in men compared to women. The predominant reason for not meeting health recommendations among the subjects is too low frequency of muscle-strengthening activities.

# Muscle activity during gait is impaired in Parkinson's Disease: a control-matched preliminary study

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**Background**: Gait disorders are frequently reported in individuals with Parkinson's disease (PD). Despite extensive research, the specific gait features affected by PD are still not clearly defined.
**Objective**: To investigate muscle activation patterns during single and dual task gait in individuals with PD compared to healthy controls (HC).

**Materials and methods:** Participants with idiopathic PD and HC were analyzed and compared in two conditions: simple and dual task walking. Subjects were instructed to walk along a 10m straight path at comfortable speed, with the addition of a cognitive task (counting backwards) during the dual task condition. Data were collected using 3D Motion capture and surface electromyography (sEMG) to record muscle activity of both lower limbs i.e., gluteus maximus, biceps femoris, rectus femoris, vastus medialis, gastrocnemius medialis, soleus and tibialis anterior. Qualisys Track Manager (QTM), Visual3D and MATLAB, were used to analyze data. Comparisons were performed to study the effect of task (simple vs dual) and the effect of group (PD vs HC). After normalization of the sEMG signals and the gait cycle, Statistical Parametric Mapping (SPM) was used to perform statistical analysis.
**Results**:12 PD (age 63.2± 6.1 yrs old; H&Y 2 ± 0.62; disease duration 8.20 ± 7.8) and 6 matched HC (age 60.8± 9.4 yrs old) were analyzed. The sEMG of PD showed an increase in the activation of gluteus maximus, biceps femoris and rectus femoris, throughout the gait cycle with differences being significant during early to mid-stance and in late swing, both in single and dual-task gait. A decreased activation of medial gastrocnemius and soleus muscles during the push-off phase was found, which however was not found to be significant.
**Conclusion**: We highlighted an increase in muscle activation in PD during early stance, associated with a reduced activity of the medial gastrocnemius and soleus during the push off phase.

# Investigating Differences in Eye Tracking Metrics Between Numeric and Alphanumeric Test Complexities in the Trial Making Test

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Tailoring interventions for neurological impairment relies on precise diagnosis of deficits across multiple functional domains. Existing clinical scales to assess cognitive-motor function typically offer limited performance metrics in a single domain. By digitizing these tools, it is possible to capture the spatial-temporal aspects of behavior, providing insight into domain-specific deficits. Furthermore, quantitative capture of eye-hand coordination can provide unparalleled insights about the interplay of the cognitive-visual-motor triad that is so critical for complex behavior. With this aim, we developed a novel digitized TMT (dTMT) with integrated eye tracking to allow for the extraction of more in-depth outcome measures, necessary for multi-domain assessment. The dTMT shows strong criterion validity in young healthy individuals in comparison to the original paper TMT. Healthy young participants (N=21) completed numeric (1-2-3-4...) and alphanumeric (1-A-2-B...) versions of the eye tracking-integrated dTMT following informed consent. Hand path, gaze path, and spatial and temporal distribution of fixation targets relative to hand target were measured to assess differences in the cognitive resources required between test complexities. In the alphanumeric task compared to the numeric task there was a significant ($p<0.001$) increase in the number of fixations. There was also a significant increase ($p<0.001$) in fixations on previously achieved targets. These results indicate that greater cognitive resources are required for the alphanumeric test characterized by more complex spatial planning (increased number of fixations), less attention to the peripheral visual field, and a greater strain on working memory (increased re-fixations). This work lays the foundation for the utilization of an eye-tracking integrated digitized trail making test for the detection of individualized domain-specific deficits in neurologically impaired populations.

# Motor learning of hand grip as a function of upper limb status after stroke

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Keywords: hand grip control, motor learning, stroke, functional status

**Introduction:** As a result of stroke, upper limb function is often impaired, so a key task in the rehabilitation process is to understand the functional status of the upper limb and then to improve the hand functions. The aim of the study was to map the relationship between the level in upper limb functional status following stroke and motor learning capacity.
**Methods:** In the present study, the hand function of 22 stroke survivors with hemiparesis was assessed in terms of fine motor function (Nine Hole Peg Test), gross motor function (maximum voluntary grip strength, MVC), and activities of daily living (Jebsen-Taylor Hand Function Test). Motor function of the whole upper limb was measured using the Fugl-Meyer test. Following the assessment, participants took part in a motor learning learning task aimed at mastering the precise application of hand grip force. Acquisition was performed in a variable training schedule. On the following day, forces equivalent to 25 and 40% of the MVC were applied in the retention and transfer tests.
**Results:** Results from the fine and gross motor tests and functional test showed a close correlation. There was a significant improvement in performance on the learning task. In both the functional tests and the learning task there was a large individual variation in performance between participants. Performance in the functional tests did not show a significant correlation with the ability to apply force accurately in the movement learning task during acquisition. However, constant error and absolute error in force application showed a trend-level correlation with MVC at the initial stage of learning. There was a significant correlation between the results of the force exertion without feedback and some functional tests of the transfer effect of learning.
**Conclusion:** During the initial, rapid phase of movement learning, a learning effect is observed during the application of precise grip force in hemiparetic stroke survivors. Some of the variables describing learning may be associated with functional ability, however, with high individual variability, an inferential result is expected from the inclusion of additional participants.

# The perception and coordination during pointing tasks: Testing predictions of the iso-perceptual manifold and uncontrolled manifold hypotheses

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We explored the task of pointing by a fingertip along with matching an endpoint configuration and joint angle with the contralateral arm to test predictions of two hypotheses: the uncontrolled manifold hypothesis (UCM) [4] and iso-perceptual manifold hypothesis (IPM) [3]. Each seated subject (healthy adult) performed series of fast pointing movements from the same reference position to a visual target with the right (dominant) arm in a sagittal plane and tried to match either the endpoint coordinates or the angle in an individual joint with the left arm without seeing this arm. In control trials, the right arm moved one joint at a time over a range corresponding to that joint's excursion in the pointing task and the subject tried to match accurately that joint's angle by moving the left arm without seeing this arm. All the conditions were fully randomized. A motion analysis OptiTrack system (6 cameras, 120 Hz) was used to quantify joint angles and endpoint coordinates in the steady states for both arms. The UCM framework was used to quantify multi-joint synergies stabilizing the endpoint coordinates for both arms. Constant and variable errors across repetitive trials were quantified separately over the pointing trials and over the control trials for each of the three joints (shoulder, elbow, and wrist). During the trials with matching the endpoint coordinates, both arms showed similar indices of multi-joint synergies stabilizing the endpoint spatial coordinates as reflected in higher variance along the UCM as compared to variance orthogonal to the UCM. This result contrasts an earlier observation of significantly stronger synergies in the hand with visual feedback on the total force produced by several fingers compared to the hand performing force matching without visual feedback [2]. This difference may be due to much better perception of positional variables compared to force variables in the absence of vision. We observed lower error indices during joint angle matching in the control trials when both arms moved one joint at a time compared to the trials when one arm performed the pointing task, and the other performed joint angle matching. These observations

corroborate the IPM hypothesis and extend the results of an earlier study with finger force perception.

# Healthy sitting: chair, kneeling chair or gym ball? - Effects of different types of seating on body posture

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Prolonged sitting in an incorrect position is one of the causes of posture disorders and back pain. Despite society's awareness of the negative impact of a sedentary lifestyle, the daily time spent sitting is still increasing. The enormity of the negative consequences of sedentary lifestyle creates a need for research analysing the sitting position and also to look for characteristics of correct sitting. The aim of the study was to compare a person's posture while sitting naturally versus sitting on a kneeling chair and on a gym ball; posture during standing was also measured to provide a reference point.

A comparative assessment of posture was carried out in an experimental study using the Zebris Spine ultrasound system. Twenty-two participants aged 20-26 years took part in the experimental study. The subjects were asked to sit on different types of seats for at least 2 minutes. Experimental tests were carried out to identify characteristic anthropometric points in space and then to determine parameters, i.e. trunk tilt and pelvic tilt in the sagittal plane.

Compared to standing, natural sitting on a chair increased the torso angle in 77% of subjects, sitting on a kneeling chair - in 64% of subjects, and sitting on an gym ball - in 82% of subjects. Compared to sitting in a chair, the use of a kneeler resulted in an upright trunk in 82% of subjects, with a reduction in the trunk angle from 1.2° to as much as 14°. Sitting on a gym ball resulted in 64% of subjects having an upright trunk, with a change in trunk tilt ranging from 0.7° to 9.7°. Comparing the analysed sitting positions, the lowest trunk tilt was observed when sitting on a kneeling chair (4.26°±2.34°), followed by a gym ball (6.70°±4.81°) and finally a chair (7.97°±5.36°).

When standing, the pelvis was tilted anteriorly (-10.91°±4.94°), whereas when sitting, the pelvis was tilted posteriorly. A pelvic tilt angle of 13.06°±7.88° was recorded when sitting on a chair, whereas when sitting on a kneeling chair the pelvic tilt angle was 3.23°±9.24°, when sitting on a gym ball: 10.95°±7.02°.

It can be concluded that of the sitting positions analysed, sitting on a kneeler is the least different from standing, which may suggest that it places the least loads on the lumbar spine.

**FUNDING**
This research was funded by the National Science Centre Poland, project: “Mathematical model of prediction of health consequences in musculoskeletal system as a result of sedentary lifestyle”, grant number: 2019/35/O/ST8/02719.