Enhancing Reactive Stepping Performance in Parkinson's Disease Through Action Observation with Motor Simulation

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Background and Aim Reactive stepping responses are crucial for recovering from loss-of-balance. These are impaired in people with Parkinson's Disease (PwPD), contributing to an elevated fall risk. Perturbation-based training has been proven effective for improving reactive steps, but is labor intensive and costly (1). Action Observation with Motor Simulation (AOMS) may offer a feasible, scalable alternative (2). This study evaluates whether a single AOMS training session enhances reactive stepping in PwPD. We hypothesize that the AOMS training session improves reactive stepping in PwPD.

Methods Twenty PwPD (HY 2–3) underwent an identical sequence of ten treadmill-induced perturbations (1.5 and 2.5 m/s^2) at T0 and one year follow-up (T1). Prior to the real perturbations at T1, ten randomly selected participants completed AOMS training, which involved observing and simulating reactive steps demonstrated by an avatar. The control participants (n=10) completed the perturbations without prior training. Step quality was quantified as the leg angle relative to the vertical at first stepping-foot contact.

Results We compared within-participant changes in leg angles between T0 and T1 and found that across all trials, the AOMS group improved their performance, whereas controls did not (1.7±6.4° vs -0.5± 6.1°, p=0.016). The very first trial showed the largest difference (3.7±10° vs -3.6±3.6°, p=0.028).

Conclusions Single-session AOMS training enhanced reactive step quality in PwPD. The first-trial improvements are of particular interest, as this best resembles real-life fall recovery. These results highlight the potential of AOMS as a scalable approach to reduce fall risk.

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1. McCrum et al. (2022) Front Sports Act Living. 2022;4:1015394
2. Hagedoorn et al. (2025) *Exp Gerontol*. 2025 Jan;199:112645

Keynote speaker 2 (K2)

The reasons and rational to use digital mobility outcomes (DMOs) in research and clinical practice appear face valid and straightforward.

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The potential use cases are broad and include prediction and prognostic modeling, evaluation of treatment, monitoring, stratification such as watchful waiting or proactive treatment and safety asssessment. Novel methods and hardware improvement are allowing real-world monitoring to assess physical activity and mobility. This enriches the practise of supervised assessment and PROMs. Reseachers are very motivated to use wearable technology in observational and intervention trials. The rest of the world is not. Research meets reality. Clinical uptake and regulatory acceptance have been cumbersome.

The claim that mobility is the sixth vital sign is misleading. Mobility is a sign of activity and life space but not a vital sign like a heart rate. Based on the experience of the Mobilise-D consortium that was started in 2019 the key note will discuss the achievements, pitfalls and possible reasons to neglect the potential of DMOs. This includes technical and clinical validation, epidemiological data, data from intervention trials, question on MIDs, sensor locations, and the use of commercial devices for pre-clinical assessment. Last but not least, the talk will argue for an integrated approach of DMOs in the area of digital interventions as an essential component.”

Osteoarthritis research; a multidisciplinary approach

Sita Bierma-Zeinstra

Erasmus MC, Rotterdam & TU Delft

Osteoarthritis (OA) is the most common joint disease and a major cause of physical disability. In the next decades its prevalence will almost double due to the ageing population and due to the obesity pandemic. We have no cure for OA and there are still enormous challenges in OA, ranging from poor understanding about the disease to insufficient implementation of key recommended management strategies. In this keynote examples of multidisciplinary research efforts will be given to tackle these challenges.

Ageing Affects Mechanosensitivity of Human Osteocytes

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Abstract

Introduction: With increasing age the human skeleton changes its composition and decreases in density, thereby compromising its load-bearing capacity. Embedded in the bone matrix are mechanosensitive osteocytes, which orchestrate bone adaptation to mechanical loading by regulating osteoblast and osteoclast activity. Whether age-related alterations in the bone matrix are reflected by a decrease in the mechanosensitivity of osteocytes is currently unknown. This study aimed to assess whether ageing affects osteocyte mechanosensitivity.

Methods: Human cortical bone samples were retrieved from 39 donors (age: 23-82 yrs, 25 male, 14 female). Osteocytes were either isolated and cultured as monolayer, or kept in their native matrix in bone explants. Isolated osteocytes were treated by pulsating fluid flow (PFF; 0.7±0.3 Pa, 5 Hz, 1 h), and post-cultured for 6 and 24 h. Nitric oxide (NO) release was quantified during PFF treatment using Griess reagent. Bone explants containing osteocytes in their native matrix were mechanically loaded by three-point bending (2000 microstrain, 1 Hz, 5 min), and post-cultured for 6 and 24 h. Bone stiffness was determined using a force-displacement modulus curve. Mechanosensitivity-related gene expression (cyclooxygenase-2 (*COX-2*), sclerostin (*SOST*), dentin matrix protein-1 (*DMP1*), interleukin 6 (*IL-6*)) was assessed in isolated osteocytes and explants during post-culture by RT-PCR. Linear regression analysis was used to assess a possible relationship between age and osteocyte mechanosensitivity.

Results: Isolated cell cultures responded to PFF with enhanced release of NO (2.6-fold, $p<0.001$), independent of age. Ageing did not change cortical bone stiffness in bone explants. There was a positive association between age and PFF-induced gene expression of *IL-6* ($R^2=0.38$, $p<0.05$; cell cultures from older donors showing a higher response than cultures from younger donors), but not expression of *COX-2, SOST and DMP1* in isolated osteocytes. In bone explants, age and mechanical load-induced gene expression was not significantly correlated.

Conclusion: Osteocytes isolated from aged matrix increased their ability to respond to PFF, while osteocytes in aged bone explants did not show such an effect. This suggests that alterations in structure and/or composition of the ageing bone matrix may affect osteocyte mechanosensitivity, which could, at least in part, be responsible for bone fragility leading to bone fractures during ageing.

Long-Term Evaluation of Osteoarthritis and Gait After Rotationplasty

Gitte Krebbekx, Niels Waterval, Merel Brehm, Mylene Duivenvoorden, Frank Smithuis, Robert Hemke, Inger Sierevelt, Jos Bramer, Gino Kerkhoffs, Floortje Verspoor

Background

Rotationplasty is a surgical procedure for patients with malignancies around the knee or congenital femoral defects. Altered biomechanics from gait deviations may increase the risk of osteoarthritis in the lower extremities. This study aims to evaluate osteoarthritis development in the (pseudo)knee (rotationplasty ankle), contralateral ankle and both hips, its impact on pain and daily functioning, and compares gait patterns with healthy participants to assess their relationship with radiographic OA and differences between patients with and without OA.

Method

We invited all rotationplasty patients (1980–2002, Amsterdam UMC) for radiographic, functional and gait assessments. Thirty patients (median age 47 years, follow-up 33 years) underwent radiographs of both hips, the (pseudo)knee and contralateral ankle (Kellgren–Lawrence ≥2 = OA); 29 also completed 3D gait analysis. Functional outcomes (Harris Hip Score, FAOS, AOFAS), pain, quality-of-life and sports participation were recorded. Gait variables included hip flexion angles, adduction moments/impulses and ground reaction forces. Analyses compared patients with healthy controls and between OA vs. non-OA groups, correlating findings with demographics and questionnaire results.

Results

Moderate-to-definite OA was found in 35% of ipsilateral hips versus 11% contralaterally, and in 41–43% of (pseudo)knees versus 10% in the contralateral ankle. Osteophytes and joint space narrowing predominated medially and in the subtalar region. Despite radiographic OA, hip function was largely preserved with good pain and alignment scores on FAOS and AOFAS, although sports participation and quality-of-life were reduced. OA correlated significantly with pain in the ipsilateral ankle and with Harris Hip Scores of the contralateral hips.

Compared to 27 healthy participants, patients demonstrated greater hip flexion angles (+8°, $p<0.001$), higher joint impulses in the contralateral knee and hip ($p<0.05$) and increased peak vertical ground reaction force on the contralateral limb ($p<0.001$). No significant associations emerged between radiographic OA and gait deviations or walking energy cost.

Conclusion

Decades after rotationplasty, high rates of OA are observed in the ipsilateral hip and (pseudo)knee. Nevertheless, functional outcomes remain generally good, though sports participation and quality-of-life are diminished. Gait deviations are evident, especially in the contralateral limb, but do not (yet) correlate with radiographic OA, suggesting potential risk for future degeneration despite preserved joint function.

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Effects of lumbar disc injury and nociception on trunk motor control during rat locomotion

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Intervertebral disc (IVD) injury may lead to mechanical instability and low-back pain. When the IVD is compromised, enhanced activation of paraspinal muscles, such as the multifidus (MF) and longissimus (ML), appears critical for maintaining spine stability. On the other hand, nociception may result in inhibition of these muscles. It is unknown how IVD injury and nociception interact. This study aimed to assess the effects of IVD injury and its interaction with muscle-derived nociception on trunk motor control during locomotion in the rat. At baseline, in vivo measurements were conducted to collect spine and pelvic kinematics and bilateral EMG signals from MF and ML during treadmill locomotion, then IVD injury was induced via needle puncture at the L4/L5. After one week, in vivo measurements were conducted before and after nociception induction by hypertonic saline injection into the lumbar MF. Spine and pelvic kinematics remained largely similar across conditions. No significant changes were found in stride duration, pelvic, lumbar and spine angle changes, variability, or movement asymmetry. Muscle activation patterns and intermuscular coordination also remained largely consistent across conditions, with MF showing bilateral synchronized activation patterns and ML showing left-right alternating activation patterns. The only significant change was an increase in EMG variability in the right MF following IVD injury. A trend toward increased MF activation was observed following IVD injury. These results suggest that IVD injury elicits localized adaptations without disrupting the global locomotor patterns. Spine instability and nociception have opposite effects on excitation of paraspinal muscles.

Beyond pain relief: Understanding the neuro-immune interface of spinal mobilisation and manipulation

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Abstract

Neck pain is one of the most prevalent musculoskeletal complaints worldwide and a leading cause of disability and reduced quality of life. Spinal mobilisation and manipulation are widely used interventions that often provide rapid symptom relief. However, the underlying biological mechanisms remain largely unexplored. Recent findings from a randomised placebo controlled trial investigated immediate systemic neuro-immune responses following spinal mobilisation and manipulation in people with non-specific neck pain. Participants reported significant short-term reductions in pain, yet no measurable systemic neuro-immune changes were observed compared to placebo. These results underscore a critical gap in current understanding: how can manual interventions produce rapid pain relief without detectable systemic immunological shifts? Building on these insights, attention has turned to potential alternative mechanisms, including local neuro-immune responses and neurophysiological modulation, that may play a role in clinical outcomes. By integrating clinical evidence with emerging knowledge from neuro-immunology, the field is moving toward a more mechanistic understanding of how manual therapies influence musculoskeletal pain.

Knee Mechanical Constraint Does Not Drive the Alteration in Neural Control of Plantar Flexors During Gait in Individuals with Non-Neurological Knee Flexion Contracture

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Knee flexion contracture (KF) occurs in neurological and musculoskeletal conditions (1,2). The impact of mechanical constraints on the neural control of muscles in KF remains unclear, particularly in the plantar flexors, which are commonly affected (1,2). Surface electromyography (EMG) is widely used to assess individual muscle activation patterns, while EMG-EMG coherence provides insight into neural drive and intermuscular coordination. This study aimed to compare neural control of plantar flexors during gait between individuals with chronic non-neurological KF (chronic constraint group; n=8) and healthy individuals with an artificially induced knee constraint (artificial constraint group; n=15). Bipolar surface EMG was recorded from the medial gastrocnemius (MG), lateral gastrocnemius (LG), and soleus (SOL) during 30 meters of overground walking at 1 m/s. EMG-EMG coherence was analyzed using Wavelet transforms, and statistical comparisons were performed with Statistical Parametric Mapping during the stance phase. Although groups exhibited similar knee joint constraints, the chronic constraint group showed increased muscle activity in MG, LG, and SOL at initial contact. Moreover, significantly greater EMG-EMG coherence in the alpha and beta bands was observed at initial contact between MG–SOL and MG–LG, compared to the artificial constraint group. No significant differences were found between groups in gamma band. The increased coherence may reflect greater common synaptic input mediated by spinal and supraspinal circuits, possibly as a preparatory landing strategy. These findings suggest that mechanical constraint alone does not explain altered neural control of plantar flexors, indicating central nervous system adaptations to motor impairment in non-neurological KF.

1. Attias M, Bonnefoy-Mazure A, De Coulon G, Cheze L & Armand S (2019) Gait Posture 68, 415–422
2. Cruz-Montecinos C, Pérez-Alenda S, Cerda M & Maas H (2021) J Neurophysiol 126, 516–531

Joint Pathomechanics

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Jaap Harlaar
TU Delft

Proper functioning of the joint is key to a smooth and painfree execution of motortasks, like activities of daily life. Joint function includes both movement and the transfer of load between the bones. This is enabled by its cartilage, an almost frictionless and load withstanding tissue. The mechanics of joint function might be compromised in typical joint diseases like osteoarthritis and (sports-)trauma to its structures. This lecture will focus on how joint pathomechanics can be measured and how these are related to typical joint diseases.

Enhancing Upper Extremity Function: application of Musculoskeletal Modelling for the design and optimisation of assistive technologies

Professor Edward Chadwick
University of Aberdeen, UK

In this talk, Prof Chadwick will discuss applications of biomechanical modelling in the development and optimisation of technologies and treatments for motor impairments that affect the upper limb. We have developed comprehensive 3D musculoskeletal models that have a variety of applications, including identification of abnormal motion and muscle activity patterns (eg in shoulder instability), design and optimisation of rehab interventions (eg functional electrical stimulation), and improving control of assistive devices via real-time, user-in-the-loop simulation. This talk will give a high-level overview of these applications with a focus on the opportunities provided by them and the challenges presented.

Automated dystonic posture detection of the hand from standard video recordings of children and young adults with computer vision

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Dystonia is a movement disorder characterized by involuntary movements and abnormal postures. Clinical assessment and monitoring of dystonia is challenging, but crucial for optimal treatment. Current advances in computer vision offer potential to develop new movement analysis techniques for this group (1,2). Here we explored a video-based deep learning approach. We hypothesized that within hand images extracted from videos a dystonic hand posture can be automatically detected. A total of 199 rest videos were available from 94 participants with dystonia (age 5-24 years). In each video the right hand was automatically selected using MediaPipe. Depending on the variety of hand postures within the video 1-2 images were selected, leading to 269 hand images. Additionally rest hand images from five typically developing children (TDs) were added to the dataset, to allow the model to learn from the whole functional spectrum. The dataset of 274 images was then manually annotated by a trained assessor for "Dystonia YES" or "Dystonia NO", and split in a training- and test set (80%/20%), by subject-wise random split, with the images of TDs being forced into the training set. A binary image classification model was trained using MobileNetV2 architecture. The trained model performed very well in correctly identifying true positive instances (i.e. dystonia), with only some instances being incorrectly identified as dystonia; Model performance: precision 0.77, sensitivity 0.91 and F1 score 0.84 and specificity of 0.47. For clinical use the model will be further improved with a larger dataset and by defining an optimal classification threshold.

1. Haberfehlner H, van de Ven SS, van der Burg SA, Huber F, Georgievska S, Aleo I, Harlaar J, Bonouvrié LA, van der Krogt MM, Buizer AI (2023), Front Robot AI, 2023 Mar 2;10:
2. Haberfehlner H, Roth Z, Vanmechelen I, Buizer AI, Vermeulen RJ, Koy A, Aerts JM, Hallez H, Monbaliu E. (2024), Neurorehabil Neural Repair, 38(7):479-492

Inertial Measurement Unit-based shoulder joint angles: accuracy assessment using OpenSense framework

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Introduction: Accurate measurement of shoulder joint range of motion is critical for motor impairment assessment, yet traditional clinical tools such as goniometers are often subjective, lack sensitivity, and capture limited motion [1]. Inertial Measurement Units (IMUs) can provide objective, continuous, and remote assessment of shoulder kinematics. However, challenges remain, including time-efficient workflows, precise sensor-to-segment calibration, and susceptibility to magnetic disturbances. OpenSense [2] offers a standardized framework for estimating joint angles from IMU data, including IMU-to-segment alignment and inverse kinematics. This study assessed the accuracy of shoulder joint angles derived from IMUs using the OpenSense framework against gold-standard skin-marker-based optoelectronic motion capture (OMC) inverse kinematics.

Methods: Twenty participants with normal shoulder function (age = 30.4 [6.0] years; 9 males) performed clinical and functional tasks. Kinematics of the thorax, clavicle, scapula, humerus, and forearm were simultaneously recorded with OMC and IMUs. IMUs were manually aligned with the body segments, and their orientations were estimated using a complementary filter. The Delft Shoulder and Elbow Model was used to compute IMU-based and OMC-based kinematics. Agreement was quantified using root mean square errors (RMSE) and consistency using correlation coefficient (CC).

Result: Highest accuracy was observed for glenohumeral elevation (CC = 0.81, RMSE = 4.86°) and elbow flexion/extension angles (CC = 0.86, RMSE = 7.70°). Glenohumeral axial rotation and elevation plane also showed strong correlations (>0.79) despite higher RMSEs (>12°). Acromioclavicular joints showed lower correlations (≈ 0.35-0.59) and higher RMSEs (5-10.2°), likely due to small motion ranges and soft tissue artefacts. Sternoclavicular joints demonstrated moderate agreement (5.07-10.92°).

Conclusion: The OpenSense workflow enables reasonably accurate estimation of primary shoulder and elbow joint angles and shows potential for low-cost 3D kinematic assessment. Lower accuracy for scapular and clavicular motions, as well as gimbal lock occurrences, highlight the need for further refinement of the framework for consistent and physiologically accurate outputs.

Acknowledgments

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1. Stefana E, et al., Sensors, vol. 21, 2021.
2. Al Borno M, J Neuroeng Rehabil, vol. 19, p. 22, 2022.

Upper limb motor impairment in cancer survivors with chemotherapy-induced peripheral neuropathy

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Aim: More than 30% of cancer survivors are affected by chemotherapy-induced peripheral neuropathy (CIPN) six months post-neurotoxic treatment. Despite anecdotal reports, published evidence regarding the detrimental impact of CIPN on upper limb function is scarce. Our study aims to characterize upper limb function in people with CIPN. We hypothesize that CIPN participants will demonstrate poorer sensory and motor function compared to healthy age and sex-matched controls.
Methods: to date, 28 cancer survivors with CIPN at least 6 months post neurotoxic treatment completion (age range 48-79 years) have been recruited and age and sex-matched with 28 healthy controls identified from an existing dataset [1]. Participants have completed the Disability of the Arm, Shoulder and Hand questionnaire (DASH) and undertaken the upper limb physiological profile assessment which comprises assessments of handgrip strength, finger press simple reaction time, nine-hole peg, bimanual pole coordination, hand tactile sensitivity and shirt buttoning [1].
Results: Compared with controls, CIPN participants perform worse in the upper limb physiological profile assessment ($P<0.05$) and report greater upper limb impairments (higher DASH score) ($p<0.05$). Among CIPN participants, weak handgrip and longer time to put on and button a shirt are correlated with higher DASH scores ($p<0.05$).
Conclusions: As hypothesized, our preliminary results demonstrate significant upper limb sensory and motor impairments in cancer survivors with CIPN compared with healthy controls. Deficits in upper limb strength and function are associated with more severe self-reported impairments, emphasizing the need to develop and implement upper limb rehabilitation programs for people with CIPN.

1. Ingram LA, Butler AA, Walsh LD, Brodie MA, Lord SR and Gandevia SC (2019). Plos One 14, e0218553.

Reliability of the Humeral Head Centralization Test in Evaluating Anteriorly Instable Shoulders -Reflecting on the chosen approach

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Background: This study aimed to establish an easily applicable, reliable parameter for quantifying anterior translation of the humeral head during active arm movements.
Study design: Case-control study with an inter-examiner agreement and reliability analysis.
Methods: The shoulders of 25 patients with anterior shoulder instability and 25 pain-free control group individuals were examined. In both groups, the translation of the humeral head during external rotation of the shoulder and extension of the elbow was assessed using ultrasound by a physical therapist. Further, the subjective function and objective stability of the shoulders of the patients were assessed using patient-reported outcome measures and physical examination. After one week, the ultrasound assessment was repeated by both the physical therapist and a radiologist.
Results: In patients a significantly greater anterior translation of the humeral head was observed compared to participants in the healthy control group during active test movements. The test-retest reliability of the physical therapist demonstrated poor consistency for the external rotation movement and moderate consistency for the extension movement of the elbow. The inter-tester reliability of the physical therapist and radiologist was moderate for both movements.

Conclusion: There was a significant difference between patients and controls observed in the translation of the humeral head during active extension of the elbow ($p < .001$). Still, the findings of this study further emphasize the difficulties in measuring anterior glenohumeral translation during active motion within a clinically feasible setup. Therefore, this novel test, in its current form, cannot be recommended for use in clinical practice or research.

Poster presentations

P1: Alexander Zero

Peripheral regulation of maximal human motor unit firing rates during fatiguing activation

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Two separate experiments were conducted to explore factors involved in the reduction of maximal motor unit (MU) firing rates during sustained high-intensity fatiguing muscle activation. Intramuscular tungsten microelectrodes were used to record MU activity (total n=3242). Data are mean ± standard deviation. In 10 participants (23.7±3 years, 3F) maximal MU firing rates from the tibialis anterior (pre-task 40.1±11.5 Hz) during dorsiflexion were compared following a sustained 60s maximal voluntary contraction (MVC), and separately following 60s of supramaximal tetanic peripheral nerve stimulation (initial torque ~81% MVC). Following the 60s tasks the ~30% reduction in both MVC torque and maximal firing rates were not significantly different between tasks, or during 10-min of recovery ($P=0.08$ and $P=0.14$, respectively). Therefore, voluntary activation of descending pathways is not directly responsible for the reduction of maximal firing rates after sustained high-intensity activation. Rather, peripheral factors likely originating from the fatigued muscle may be responsible for rate reductions during voluntary efforts. To explore this hypothesis, participants (24.7±3, n=10, 3F) underwent a sub-maximal fatiguing task (duty cycle, 0.6s) of knee extensions at 30% MVC for 30-min, shown previously to reduce MVC torque with negligible metabolic disturbances [1]. At 30-min MVC torque was reduced to 61.7 ± 17.4% of pre-task ($P<0.001$), however, grouped maximal firing rates from the vastus lateralis and medialis (24.1±8.9Hz) were not different ($P=0.16$) from pre-task (24.7±9.2Hz). Combined these experiments support the hypothesis that firing rate moderation during fatigued MVCs is due to reflexive inhibition from changes in the contractile state of the muscle.

1. Vøllestad N, Sejersted O, Bahr R, Woods J, Bigland-Ritchie B (1988) J Applied Physiol 64, 1421-1427

P2: Anne van Dijken

Evaluating the Steep Ramp Test for HIIT Prescription in Clinical Rehabilitation

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Objectives
The Steep Ramp Test (SRT) is widely used to assess fitness in clinical settings, but evidence for its use in exercise prescription remains limited (1). This study evaluated the adequacy of the (SRT) for determining high- and low-intensity workloads for High-Intensity Interval Training (HIIT) in rehabilitation, and for assessing maximal exercise performance.

Design and Subjects
A retrospective analysis was conducted using real-life data from 60 individuals (different diagnoses) enrolled in a clinical rehabilitation fitness program.

Methods
SRT outcomes were compared to those from Cardiopulmonary Exercise Testing (CPET), with intensity zones defined by ventilatory thresholds (VT1 and VT2). Optimal percentages of SRT maximal power (Pmax-SRT) were identified by balancing zone classification accuracy and deviation from CPET thresholds. Agreement and correlations between SRT- and CPET-derived measures were assessed. Subgroup analyses explored diagnostic influences.

Results
Prescriptions at 25% (low) and 65% (high) of Pmax-SRT showed acceptable accuracies (80%, 82%) and average deviations (-19W, +20W) from CPET thresholds. However, large inter-individual variability in deviations was observed. Pmax-SRT and Pmax-CPET were strongly correlated ($r = 0.89$, $p < 0.001$), but agreement was low (ICC = 0.49), with SRT overestimating Pmax by 72W on average. No significant diagnostic effects were found.

Conclusions
The SRT may help guide HIIT prescriptions at the group level using 25% and 65% of Pmax-SRT. However, substantial variability and poor agreement with CPET outcomes highlight the risk of under- or overtraining when using fixed percentages, underscoring the need for clinical discretion. Larger subgroup analyses and external validation are warranted.

1. Trul-Kreuze IA, Akkerman M, Kieboom EAM, Nieuwenhuis MK, Houdijk H, Bongers BC (2024). Arch Phys Med Rehabil 105(11):2198-213.

Sonomyography of the gastrocnemius medialis muscle during walking in persons post-stroke

Lynn Bar-On [1], Daan De Vlieger [1,2], Hannah-Eva Decorte [3], Babbette Mooijekind [1,4,5], Francesco Cenni [6], Eva Swinnen [2], David Beckwée [2], Anke Van Bladel [1,2,7]

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Pathology-specific changes in the gastrocnemius medialis (GM) are common in neurological disorders. When combined with 3D kinematic data, sonomyograhy (SMG) can be used to quantify the behaviour of the GM during gait. We explored whether collecting GM SMG affected gait kinematics in persons post-stroke and healthy controls and visualized SMG differences in GM behaviour between these populations.
3D lower-limb kinematics were collected from 6 subjects 7±7m post-stroke and 6 age- and sex-matched controls (mean age 54±8y, 5 males) while treadmill walking with and without an ultrasound-probe positioned on the GM muscle-tendon junction (MTJ). Spatiotemporal parameters and sagittal plane kinematic hip, knee and ankle data were compared between conditions ($\alpha=0.05$). Semi-automatic MTJ-tracking software was used to visualise relative muscle, tendon and muscle-tendon-unit length change relative to length at initial contact (1).
GM SMG had no significant effects on spatiotemporal or kinematic data in either group. Walking speed differed between post-stroke and control subjects (0.6±0.3 vs. 1.1±0.3m/s, $p<0.004$). GM muscle length changed minimally over the entire gait cycle in stroke (3.99±5.22mm) compared to control (15.66±8.23mm).
Confirming findings in cerebral palsy (2), GM SMG had minimal effects on the gait of persons post-stroke walking at a self-selected speed on a treadmill. Ankle and knee kinematic impairments post-stroke were accompanied primarily by reduced GM muscle-belly length changes, reflective of GM paresis. SMG data collection in persons post-stroke may provide insights on dynamic GM behaviour during walking, possibly leading to the finetuning of rehabilitation strategies to improve gait performance in this population.

References

1. Cenni (2018) Ultrasound Med Biol 44(12),2505-2518.
2. Mooijekind B (2023) Gait & Posture.

Exploring the association between muscle characteristics and exercise outcomes in rheumatic diseases and sarcopenia: protocol for the Care for Muscle (C4M)

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Muscle weakness is a common symptom in rheumatoid arthritis (RA), osteoarthritis (OA), and sarcopenia (SARC), yet underlying mechanisms and exercise responses differ. In RA, systemic inflammation contributes to increased intramuscular oxidative stress and mitochondrial dysfunction. OA mechanisms are less defined, while SARC involves reduced muscle protein synthesis and atrophy. This study investigates intramuscular determinants of exercise responsiveness to guide personalized treatment. We hypothesize that individual exercise responses are influenced by disease-specific muscle morphology, mitochondrial function, and systemic inflammation.

In a two-arm, parallel-group exploratory trial, 69 patients (23 RA, 23 OA, 23 SARC) will be randomized to 8 weeks of either strength training (n=34) or muscle endurance training (n=35), stratified by disease type and sex. Intervention includes twice-weekly supervised sessions using a controlled cable-pulley system (Reforter™) and one home-based session. The primary outcome is isokinetic peak muscle strength (Nm), assessed using the Biodex system. Secondary outcomes are muscle morphology (via 3D ultrasound of vastus lateralis), mitochondrial function (via high-resolution respirometry in muscle biopsies), systemic inflammation (via ELISA or multiplex serum analysis), and muscle endurance (isokinetic fatigue tests, 6-minute walk test, Chair Stand Test, FitMáx© questionnaire).

This study will explore differential responses to muscle strength and muscle endurance training in patients with RA, OA, and SARC, offering novel insights into the molecular mechanisms of muscle weakness. Findings aim to enhance understanding of intramuscular pathways and inform development of personalized, pathology-based exercise interventions to improve functional outcomes in these populations.

1. Steinz MM, Persson M, Aresh B, et al. Oxidative hotspots on actin promote skeletal muscle weakness in rheumatoid arthritis. JCI Insight. 2019;5(9):e126347. Published 2019 Mar 28. doi:10.1172/jci.insight.126347

2. Sobejana, M., Al Beiramani, M., Zwezerijnen, G. J. C., van der Kooi, A., Raaphorst, J., Meskers, C. G. M., van der Esch, M., van der Laken, C. J., & Steinz, M. M. (2025). Methodology Development for Investigating Pathophysiological [18F]-FDG Muscle Uptake in Patients with Rheumatic Musculoskeletal Diseases. *Biomedicines*, *13*(2), 465. https://doi.org/10.3390/biomedicines13020465

P5: Ahmed Elsayed

The effect of biofeedback on dysphagia in stroke patients: A systematic review

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Abstract

Background: Dysphagia is a common and serious complication following stroke, affecting up to 78% of patients (1) and leading to increased morbidity and decreased quality of life. Surface electromyography (sEMG) biofeedback has emerged as a promising adjunctive therapy for dysphagia rehabilitation (2). However, its effectiveness remains under-investigated in high-quality trials.

Objective: To systematically review and analyze the effect of biofeedback therapy with surface electromyographic (sEMG) recordings for post-stroke patients on swallowing in a focus on RCTs.
Methods: A thorough search was performed in PubMed, Scopus, Web of science, and Cochrane Library databases according to specific keywords and Mesh terms. Inclusion criteria. The present review included the following types of studies: RCTs that evaluated the effect of sEMG biofeedback therapy for dysphagia in patients following stroke. The methodological quality of the included studies was evaluated via the PEDro scale, and the results were integrated in a narrative form.
Results: Six RCTs that included a total of 204 patients were eligible. Ranging between 2 and 5 weeks, the interventions were frequently also undertaken alongside traditional swallowing exercises or neuromodulation. Most studies showed improvement of functional swallowing outcomes (FOIS, PAS, DOSS) and higher levels of improvement in the experimental group than in the control group using sEMG biofeedback. The findings failed to be consistently statistically significant, however. Methodological limitations consisted of non-blinded assessments, small sample sizes, outcomes assessed in a heterogeneous manner.

Conclusion: sEMG biofeedback therapy appears to be a safe and potentially effective intervention for improving swallowing function in post-stroke dysphagia patients, particularly when used alongside conventional therapy.

Keywords: Stroke, Dysphagia, Biofeedback, Surface Electromyography, sEMG, Swallowing, Systematic Review

References

1. Martino R, Foley N, Bhogal S, Diamant N, Speechley M,Teasell R. Dysphagia after stroke: incidence, diagnosis, and pulmonary complications. Stroke. (2005) 36:2756 63. doi: 10.1161/01.STR.0000190056.76543.eb.
2. Crary MA, Carnaby GD, Groher ME, Helseth E. Functional benefits of dysphagia therapy using adjunctive sEMG bio feedback. Dysphagia Sum. 2004;19(3):160- 164. doi:10.1007/ s00455- 004- 0003- 8.

P6: Mohamed Emam

Proprioceptive Training Improves Postural Stability and Reduces Pain in Cervicogenic Headache Patients: A Randomized Clinical Trial

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Background: Headache is one of the leading causes of disability in the world [1]. Neck proprioception, pain, and postural control are interconnected in both healthy individuals and those with chronic neck pain [2]. This study examines the effects of proprioceptive training using a gaze direction recognition task on postural stability and pain in cervicogenic headache patients.
Methods: Patients with cervicogenic headache (n = 34, age: 35–49 y) were randomized into a control group (CON), receiving only selected physical therapy rehabilitation or to an experimental group (EXP), performing proprioceptive training using a gaze direction recognition task plus selected physical therapy rehabilitation. Both programs consisted of 24, 60 min long sessions over 8 weeks. Postural stability was assessed by the modified clinical test of sensory integration of balance (mCTSIB) and a center of pressure test (COP) using the HUMAC balance system. Neck pain was assessed by a visual analog scale.
Results: In all six tests, there was a time main effect ($p < 0.001$). In three of the six tests, there were group by time interactions so that EXP vs. CON improved more in postural stability measured while standing on foam with eyes closed normalized to population norms, COP velocity, and headache (all $p \leq 0.006$). There was an association between the percent changes in standing on foam with eyes closed normalized to population norms and percent changes in COP velocity ($r = 0.48$, $p = 0.004$, $n = 34$) and between percent changes in COP velocity and percent changes in headache ($r = 0.44$, $p = 0.008$, $n = 34$).
Conclusions: While we did not examine the underlying mechanisms, proprioceptive training in the form of a gaze direction recognition task can improve selected measures of postural stability, standing balance, and pain in cervicogenic headache patients.
Keywords: gaze direction recognition; balance; motor imagery; neck pain; HUMAC balance system
[1] Pillai, S.; Zhang, N. The Role of Manual Therapies in the Treatment of Headache Disorders. Curr. Neurol. Neurosci. Rep. **2023**, 23, 399–405.
[2] Eva-Maj, M.; Hans, W.; Per-Anders, F.; Mikael, K.; Mans, M. Experimentally induced deep cervical muscle pain distorts head on trunk orientation. Eur. J. Appl. Physiol. **2013**, 113, 2487–2499.

Knee Mechanical Constraint Does Not Drive the Alteration in Neural Control of Plantar Flexors During Gait in Individuals with Non-Neurological Knee Flexion Contracture

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Knee flexion contracture (KF) occurs in neurological and musculoskeletal conditions (1,2). The impact of mechanical constraints on the neural control of muscles in KF remains unclear, particularly in the plantar flexors, which are commonly affected (1,2). Surface electromyography (EMG) is widely used to assess individual muscle activation patterns, while EMG-EMG coherence provides insight into neural drive and intermuscular coordination. This study aimed to compare neural control of plantar flexors during gait between individuals with chronic non-neurological KF (chronic constraint group; n=8) and healthy individuals with an artificially induced knee constraint (artificial constraint group; n=15). Bipolar surface EMG was recorded from the medial gastrocnemius (MG), lateral gastrocnemius (LG), and soleus (SOL) during 30 meters of overground walking at 1 m/s. EMG-EMG coherence was analyzed using Wavelet transforms, and statistical comparisons were performed with Statistical Parametric Mapping during the stance phase. Although groups exhibited similar knee joint constraints, the chronic constraint group showed increased muscle activity in MG, LG, and SOL at initial contact. Moreover, significantly greater EMG-EMG coherence in the alpha and beta bands was observed at initial contact between MG–SOL and MG–LG, compared to the artificial constraint group. No significant differences were found between groups in gamma band. The increased coherence may reflect greater common synaptic input mediated by spinal and supraspinal circuits, possibly as a preparatory landing strategy. These findings suggest that mechanical constraint alone does not explain altered neural control of plantar flexors, indicating central nervous system adaptations to motor impairment in non-neurological KF.

1. Attias M, Bonnefoy-Mazure A, De Coulon G, Cheze L & Armand S (2019) Gait Posture 68, 415–422
2. Cruz-Montecinos C, Pérez-Alenda S, Cerda M & Maas H (2021) J Neurophysiol 126, 516–531

P8: Arianne Gravesteijn

Sustained Benefits of a Multi-Domain Lifestyle Intervention in Multiple Sclerosis (LIMS): A 24-Month Follow-Up

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Introduction: Multiple sclerosis (MS) often results in physical, cognitive, and psychological impairments, significantly impacting life. A s current disease-modifying therapies fall short in halting disease progression, there is a growing interest in the potential of modifiable lifestyle factors to improve outcomes.

Objectives/aims: To examine the long-term effects of a multi-domain lifestyle intervention, promoting a Mediterranean diet, physical activity, stress management, and sleep, on MS.

Methods: In the LIMS study, 500 people with MS (age 47±10; 85% female) participated in a 3-month lifestyle program with 21 months follow-up. Patient-reported outcome measures were collected at 3-month run-in, baseline, post-intervention, and at 3-, 6-, 12-, 18-, and 24-months follow-up. The primary outcome was MS-related impact on daily functioning (MSIS-29). Secondary outcomes included quality of life, general health, and MS-specific symptoms. Longitudinal changes were analyzed using mixed-effects models.

Results: Participants showed significant improvements in the MSIS-29 physical (β =–2.62, 95%CI: –3.58; –1.65) and psychological subscale (β =–3.50, 95%CI: –4.65; –2.36). Psychological improvements persisted up to 24 months (β = –3.10, 95%CI: –4.29; –1.91), while physical improvements only remained significant at 6- and 18-months follow-up. Sustained benefits were also seen in mental quality of life, fatigue, depression anxiety, and anthropometrics at 24 months.

Conclusion: A multi-domain lifestyle intervention reduced the psychological impact of MS and improved mental quality of life, fatigue, mood, and general health over 24 months. Physical improvements were less durable. These findings support lifestyle interventions as valuable adjuncts to conventional MS management.

P9: Sarah Zandvliet

Deficient muscle coordination patterns of reactive stepping responses in people with chronic stroke

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Background: People with stroke often have persistent balance impairments impacting their mobility. Several studies have been conducted to identify stroke-related deficits in neuromuscular responses to balance perturbations.[1,2] Yet, the majority of these studies involved low-intensity, non-stepping perturbations, whereas falling typically occurs at high-intensity perturbations where stepping is a key saving strategy.
Objective: We aimed to identify deficits in muscle coordination patterns of reactive stepping in people with stroke (PwS).
Methods: 32 PwS performed multidirectional stepping responses with their paretic and non-paretic leg. We determined step quality by the leg angle of the stepping leg. Nonnegative matrix factorization were used to characterize stance- and swing-leg muscle coordination patterns. After which the number of synergies that could account for >80% of the total variance (VAF) was determined.
Results: We observed smaller leg angles in PwS in lateral, posterolateral and posterior directions, particularly with the paretic leg. Five muscle synergies were identified for the swing leg $VAF_{Paretic}$=0.84±0.02, $VAF_{Non\text{-}Paretic}$=0.84±0.02) and stance leg $VAF_{Paretic}$=0.85±0.02, $VAF_{Non\text{-}Paretic}$=0.84±0.02). Three synergies were less frequently represented during paretic step execution. For the synergy with prominent gluteus medius involvement, underrepresentation was associated with lower Fugl-Meyer lower-extremity scores.
Conclusions: The finding of deficient synergy structure and activation during reactive stepping complements and extends insights into balance related impairments after stroke. Our presented methodology allows us to identify whether training-induced gains in reactive step quality are related to optimization of pre-existing coordination patterns, or whether some degree of behavioral restitution (i.e. return to 'normal' coordination patterns) may still be possible.

References:

1. de Kam D, Roelofs JMB, Bruijnes A, Geurts ACH, Weerdesteyn V (2017) Neurorehabil Neural Repair 31(8):708-716.
2. Marigold DS, Eng JJ (2006) Exp Brain Res. 171(4):459-68.

P10: Federica Scarpellini

Do emotions affect associative memory performance in early-Parkinson patients?

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Introduction:
Literature indicates that emotional states influence adaptive behavior in reversal learning tasks (1). In Parkinson’s disease (PD), reduced dopamine levels impair the ability to learn new information (2). Further investigation is needed to understand the neural mechanisms linking emotional states with learning behavior.
Objectives:
This study aims to examine whether associative memory involving emotional states is impaired in early-stage PD and how it is affected by L-DOPA therapy. We will develop a computational model of the Basal Ganglia to simulate individual behavior and identify a small set of parameters that reproduce group-level performance.
Methods:
We will include 46 early-stage PD patients and 46 healthy controls. Two reversal learning tasks will be used, one with internally induced emotions and one with externally induced emotions. We will compare performance (accuracy, reaction time) across three groups: controls, ON-state PD patients (with L-DOPA), and OFF-state PD patients (without L-DOPA). A computational model will be fitted to individual behavioral data. An automated parameter estimation procedure will identify key parameters associated with group-level behavior.
Expected Results:
Preliminary results might show significant differences in reaction time and in performance accuracy between the control vs. PD-ON vs. PD-OFF groups. The model should be able to replicate individual performance and highlight parameters that capture group-level behavior.
Conclusion:
This study will clarify how emotional states influence learning in PD and how L-DOPA modulates this effect. Refining existing Basal Ganglia models by identifying key parameters will help reveal the neural basis of emotion-related learning and inform future therapeutic strategies.

1. Nashiro, K., Sakaki, M., Nga, L., & Mather, M. (2012). Differential brain activity during emotional versus nonemotional reversal learning. *Journal of Cognitive Neuroscience*, *24*(8), 1794-1805.
2. Cools, R., Clark, L., Owen, A. M., & Robbins, T. W. (2002). Defining the neural mechanisms of probabilistic reversal learning using event-related functional magnetic resonance imaging. *Journal of Neuroscience*, *22*(11), 4563-4567.

P11: Yuge Zhang

An open-source, externally validated neural network algorithm to recognize daily-life gait of older adults based on the lower-back sensor

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Background: About one-third of older adults fall each year, mostly while walking. Gait measures from inertial measurement units (IMUs) can help predict fall risk and monitor rehabilitation. Accurate gait recognition from daily-life activities is a crucial first step.

Aim: This study aimed to develop an open-source and externally validated algorithm of daily-life gait recognition for older adults. The effects of the number of data channels and data augmentation on model performance will also be explored.

Methods: A convolutional neural network was trained for gait recognition. The data for model training was lower-back sensor data from 20 older adults (mean age 76 years), with annotated synchronized activity labels in semi-structured and daily-life conditions. The model was trained based on data from six channels (accelerations and angular velocities) and three channels (accelerations) under conditions with and without data augmentation, respectively. External validation was evaluated based on lower-back sensor data collected from 47 stroke survivors (mean age 72.3 years) in balance and walking tests.

Results: The best model performance on external validation dataset was accuracy 99.4%, precision 98.9%, sensitivity 95.9%, F1-score 97.4% and specificity 100% on the version of 6 channels without data augmentation.

Conclusion: The CNN model developed in this study provides a reliable and externally validated approach to detect real-world gait episodes from healthy and impaired OA based on lower back IMU. This can be generally applied to people who walk slowly and allows it to be updated for specific populations

User experiences of the Cue2walk smart cueing device for freezing of gait in people with Parkinson's disease

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Freezing of gait (FoG) impairs mobility and daily functioning and increases the risk of falls, leading to a reduced quality of life (QoL) in people with Parkinson's disease (PD). The Cue2walk, a wearable smart cueing device, can detect FoG and hereupon provides rhythmic cues to help people with PD manage FoG in daily life. This study investigated the user experiences and device usage of the Cue2walk, and its impact on health-related QoL, FoG and daily activities. Twenty-five users of the Cue2walk were invited to fill out an online survey, which included a modified version of the EQ-5D-5L, tailored to the use of the Cue2walk, and its scale for health-related QoL, three FoG-related questions, and a question about customer satisfaction. Sixteen users of the Cue2walk completed the survey. Average device usage per day was 9 hours (SD 4). Health-related QoL significantly increased from 5.2/10 (SD 1.3) to 6.2/10 (SD 1.3) ($p = 0.005$), with a large effect size (Cohen's $d = 0.83$). A total of 13/16 respondents reported a positive effect on FoG duration, 12/16 on falls, and 10/16 on daily activities and self-confidence. Customer satisfaction was 7.8/10 (SD 1.7). This pilot study showed that Cue2walk usage per day is high and that 15/16 respondents experienced a variety of positive effects since using the device. To validate these findings, future studies should include a larger sample size and a more extensive set of questionnaires and physical measurements monitored over time.

P13: Michelle Verhoeven

Exploring gait adaptations during dual-tasking in typically developing children and children with Developmental Coordination Disorder: A systematic review and meta-analysis

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Rhythmic motor tasks are often performed while engaging in additional tasks (dual-tasking). In typically developing children (TDC), who are still refining their motor skills (1), and in those with motor difficulties like Developmental Coordination Disorder (DCD), dual-tasking can lead to performance decrements. This systematic review and meta-analysis examined how age and additional task-type affect rhythmic motor task performance during dual-tasking. Both were hypothesized to be key influencing factors (2). Studies involving TDC or children with DCD performing rhythmic motor tasks under both single- and dual-tasking conditions were included. Meta-analyses compared single- and dual-tasking performance using Standardized Mean Differences (SMD) for spatiotemporal, variability, and balance gait parameters. Subgroup analyses assessed the effects of age and additional task-type. DCD data were analyzed descriptively. A total of 72 studies (n=72 TDC, n=5 DCD) were deemed eligible, yielding 449 gait parameters that were included in the meta-analysis. Dual-tasking significantly affected spatiotemporal (SMD=-1.08, $p<0.001$), variability (SMD=-1.04, $p<0.001$), and balance (SMD=-0.24, $p<0.05$) gait parameters in TDC. Subgroup analyses revealed greater interference from cognitive than motor tasks, with a tendency toward temporal rather than spatial gait adjustments. No significant age effect was found. Children with DCD did not show exaggerated decrements in rhythmic motor task performance, although two studies reported increased mental effort compared to TDC. These findings highlight how dual-tasking significantly disrupts spatiotemporal, variability, and balance gait parameters in TDC, and underscore the need to further investigate the increased mental effort and potential disruptions in motor control mechanisms observed in children with DCD.

1. Ruffieux J, Keller M, Lauber B & Taube W (2015) Sports Med 45 1739-58
2. Cinar E, Saxena S & Gagnon I (2021) J Mot Behav 53 509-22

P14: Arne Defour

The number of muscle synergies during walking after stroke: a potential biomarker for motor impairment

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INTRODUCTION:
Muscle synergies, reflecting primary motor control, are defined as fixed patterns of muscle co-activation or a systematic coupling of muscle activation across joints. Healthy adults typically exhibit four to five muscle synergies during walking (1). This number can be affected by injuries of the CNS such as stroke (2). Despite 60-70% of individuals post-stroke regaining independent walking, many continue to show an impaired gait quality reflected by an altered number of muscle synergies identified during walking.

HYPOTHESIS:
The paretic leg exhibits less muscle synergies during post-stroke walking compared to the non-paretic or control leg. This reduced number is expected to be associated with a shorter time since stroke, more lower extremity impairment and lower self-selected walking speed.

METHOD:
MEDLINE, Embase, and Web of Science were systematically searched (from inception to April 11, 2025) for studies using matrix factorization to extract muscle synergies during post-stroke walking.

MAIN RESULTS:
Twenty-four studies (624 individuals post-stroke) were included. The paretic leg showed significant fewer synergies than the non-paretic (SMD: -0.73; $p<0.00001$) and healthy control leg (SMD: -1.04; $p<0.00001$). The number of synergies strongly correlated with lower extremity impairment ($r=0.827$; $p<0.001$). Fewer synergies were more prevalent in the sub-acute than chronic phase ($\chi^2=15.611$; $p<0.001$).

CONCLUSION:
Stroke leads to fewer muscle synergies during walking in the paretic leg, especially in the sub-acute phase and in persons with more severe lower extremity impairment. Findings may support the potential use of muscle synergy analysis as a biomarker for motor impairment to inform rehabilitation strategies.

1. Ivanenko YP, Cappellini G, Dominici N, Poppele RE, Lacquaniti F (2005). J Neurosci. 25(31), 7238-53.
2. Van Criekinge T, Vermeulen J, Wagemans K, et al. (2020). Disabil Rehabil 42(20), 2836-2845.

Altering Body Loading in Healthy Individuals to Inform Stepping Recovery Strategies

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Falls often occur during weight-shifting tasks like step initiation (1). Understanding the mechanisms of load bearing is important for fall prevention and could inform the development of effective aids for patients with spinal or peripheral injuries, who show a higher fall risk. Here we measured muscle activation at different body loads with the aim of identifying muscles involved in weight bearing during step initiation. This allowed us to calculate spinal activation to inform new techniques for motor recovery and training.

11 healthy participants performed stepping tasks under four body weight conditions (0% supine, ~50%, ~87%, and 100% upright). Muscle activation was recorded from 13 lower limb muscles bilaterally to calculate spinal maps (2).

Load-dependent activation was measured in multiple muscles during step initiation. For the stepping limb (Figure 1), soleus, gastrocnemius lateralis, rectus femoris, vastus medialis, semimembranosus and adductor longus showed significant changes in activation upon loading. While for the non-stepping limb (Figure 2), activation was significantly different in soleus, gastrocnemius medialis, tibialis anterior and extensor digitorum. Spinal maps showed increased activation in the lower lumbar and higher sacral regions (L4-S2) at higher body weight loads.

Lower limb muscles controlled by L4-S2 spinal regions showed increased activation with body loading during step initiation. These findings provide insights to inform spinal stimulation and rehabilitation strategies for improving weight-bearing control and reducing falls risk in individuals with motor impairments.

Figure 1: Stepping limb

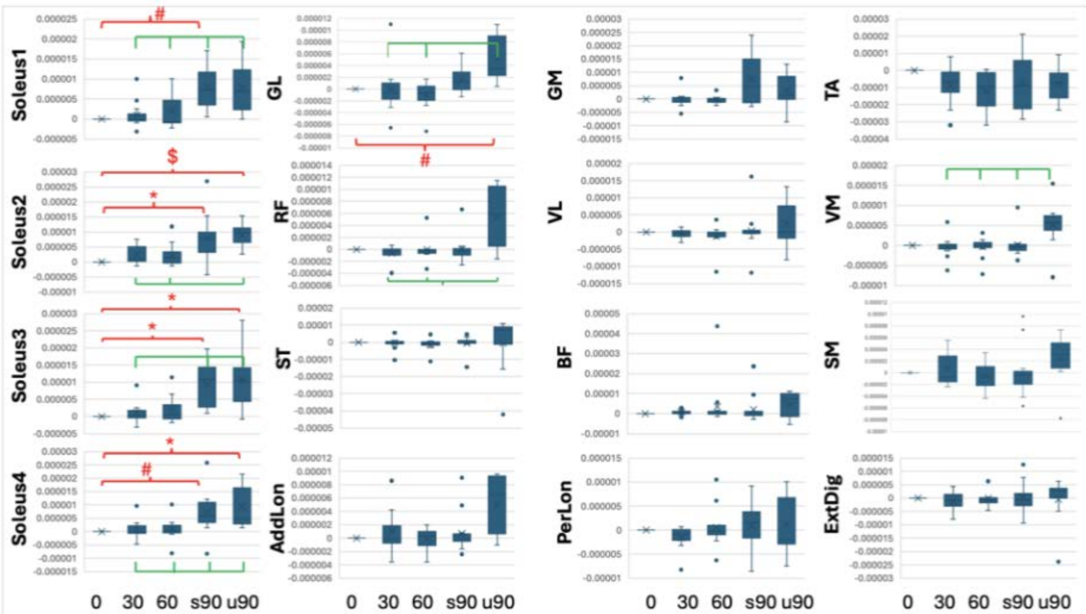
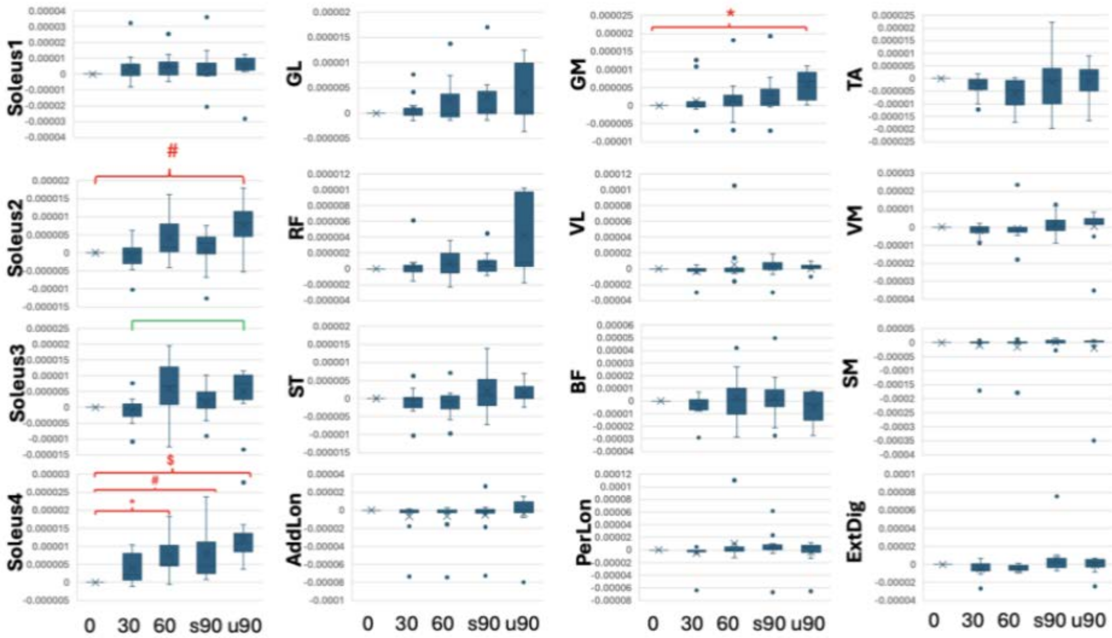


Figure 2: Non-stepping limb



For all graphs (in Figure 1 and Figure 2), the horizontal axis reports the angle of body tilt (degrees), where s90 is stepping while still supported on the motorised plinth while upright at 90 degrees, while u90 is stepping unsupported while upright (off the plinth). The vertical axis shows the muscle activation (V). Soleus was recorded in all trials as a control and is reported 4 times. GL=gastrocnemius lateralis, GM=gastrocnemius medialis, TA=tibialis anterior, RF= rectus femoris, VL=vastus lateralis, VM=vastus medialis, ST=semitendinosus, BF=biceps femoris, SM= semimembranosus, AddLon=adductor longus, PerLon=peroneus longus, ExtDig=extensor digitorum. Significant pairwise comparisons of angles relative to 0 degrees are indicated in red, where # represents $p<0.05$, * represents $p<0.01$ and $ represents $p<0.001$. Green comparisons are reported for other angles showing significant pairwise differences.

1. Khanmohammadi R, Talebian S, Hadian MR, Olyaei G, Bagheri H. Preparatory postural adjustments during gait initiation in healthy younger and older adults: Neurophysiological and biomechanical aspects. Brain Res. 2015 Dec 10;1629:240-9. doi: 10.1016/j.brainres.2015.09.039. Epub 2015 Oct 9. PMID: 26453832.
2. Ivanenko YP, Poppele RE, Lacquaniti F. Spinal cord maps of spatiotemporal alpha-motoneuron activation in humans walking at different speeds. J Neurophysiol. 2006 Feb;95(2):602-18. doi: 10.1152/jn.00767.2005. Epub 2005 Nov 9. PMID: 16282202.

P16: Ramon Boekesteijn

A narrow-based walking paradigm to challenge mediolateral stability control in people with chronic stroke

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People with chronic stroke (PwCS) often adopt a wider gait to compensate for impaired balance. Enforcing narrow-based walking could challenge this strategy, revealing balance deficits not evident during regular walking. We hypothesized that PwCS would have greater difficulty in suppressing their extrapolated center of mass (xCoM) excursion required for narrow-based gait, resulting in poorer accuracy.

Seventeen PwCS and sixteen healthy controls walked at 90% of their preferred speed on a treadmill on which a 60, 40, or 20cm wide beam was projected. Participants were instructed to place their feet within the beam as accurately as possible. Gait was recorded with 3D motion capture. Group and condition effects were assessed using linear mixed models.

Accuracy (% of steps within the beam) was high for both groups at 60cm and 40cm (>99%), but declined at 20cm (72%) for the paretic leg compared to the non-paretic leg (92%) and controls (98%) ($p<0.001$). A significant group x condition interaction was found for xCoM excursion ($p=0.017$), with PwCS showing a smaller reduction between 40cm and 20cm than controls. Across all participants, xCoM excursion, step width, and mediolateral margin of stability decreased from 40cm to 20cm ($p<0.001$), but not from 60cm to 40cm ($p>0.100$). PwCS consistently showed larger values on these parameters than controls ($p<0.002$).

PwCS failed to meet the demands of narrow-based walking on a beam of 20cm, likely due to physical limitations in reducing xCoM excursion and achieving medial foot placement with the paretic leg, along with a prioritization of stability over task accuracy.

Are there neuromuscular markers of Multiple Sclerosis?

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Multiple sclerosis (MS) is a neurodegenerative autoimmune disorder of the central nervous system (CNS) with a diverse clinical appearance that complicates diagnosis (1). As motor units (MUs) represent the final common pathway of the CNS, we hypothesized that any MS-related pathological CNS change would cause alterations in MU behavior and the resulting joint torque output during contraction. Recent advances in high-density surface electromyography (HDsEMG) offer new possibilities for non-invasive investigation of MU behavior and could potentially help to develop a new method for early MS diagnosis. Therefore, we compared MU behavior and torque variability between patients with relapsing-remitting MS (PwMS, n = 7) and healthy age- and strength-matched controls (HCs, n = 6) during submaximal fixed-end ramp-and-hold contractions of two lower limb muscles (tibialis anterior, TA; vastus lateralis, VL). Preliminary results of TA show similar mean (standard deviation) torque (PwMS: 0.14 (0.04) Nm vs. HCs: 0.15 (0.07) Nm), MU discharge rate (PwMS: 12.5 (2.3) Hz vs. HCs: 13.2 (2.4) Hz) and coefficient of variation in MU discharge rate (PwMS: 28.6 (5.7)% vs. HCs: 27.1 (9.5)%) between groups. However, despite using an automated approach for MU cleaning after decomposition, we were able to identify a higher number of Mus for PwMS (55 (7) Mus in total) compared with HCs (24 (4) MUs in total). We speculate that the larger number of identified MUs in PwMS might indicate a reduced complexity of neural drive that allows for easier MU decomposition.

1. Solomon AJ et al. (2023). Lancet Neurol. 22 (8), 750-768

P18: Edith Elgueta Cancino

Discriminating Subtle Postural Impairments Using Non-Linear Sway Metrics from Smartphones

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Mobile phone sensors have demonstrated reliability comparable to laboratory-based motion capture systems, supporting their potential use for accessible LBP risk assessment(1). This project harnesses the widespread availability and advanced technology of mobile phones to develop a predictive tool for LBP risk. By combining mobile sensor data and non-linear movement analysis we aim to develop an accessible, low-cost tool for early identification of LBP risk. We hypothesise that non-linear measures of postural sway, captured using mobile phone sensors, will provide sufficient data to train AI models to accurately discriminate between asymptomatic individuals with subtle movement impairments, who are at elevated risk of developing low back pain.
43 healthy young adults (age: 21.1 ± 3.36) and 4 adults with low back pain completed four static balance tasks in a random order. The data were simultaneously collected by the smartphone. Resultant acceleration for the sagittal and frontal plane were calculated using raw vertical/anteroposterior and vertical/mediolateral acceleration data, respectively. A multiscale sample entropy (MSE) analysis was performed on each of the postural acceleration timeseries using 15-time scales (2). The area under the complexity curve was calculated to obtain the complexity index.
Preliminary results: Mixed-effects modelling revealed significant main effects and interactions between group, movement plane, and sensor type. Post-hoc comparisons showed that healthy group exhibited significantly lower entropy values compared to individuals with low back pain, in the sagittal and frontal planes. These findings support the hypothesis and demonstrate the potential of mobile sensor-based entropy measures fo7r early identification of LBP risk.

References

1. J.J. Craig, A.P. Bruetsch, S.G. Lynch, J.M. Huisinga, Clin Biomech 49 (2017) 16-21
2. M.A. Busa, S.L. Jones, J. Hamill, R.E. van Emmerik, Gait Posture 45 (2016) 7-11

P19: Cassandra D’Amore

Development and Validation of the Canadian Physical Performance Battery in the Canadian Longitudinal Study on Aging

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The objectives of this analysis were to: 1) develop a Canadian Physical Performance Battery (CPPB) summary score for both middle-aged and older women and men and 2) validate the CPPB score across age and sex groups. The CPPB includes four components, 4-meter gait speed, 5-repetition chair-stand, single leg stance, and Timed Up and Go. Each component is scored from 0 to 4 with total scores 0-16 (higher is better). Analyses were completed with ≅30,000 participants 45-85 years old in the Canadian Longitudinal Study on Aging. Scoring cut-offs were created using weighted percentiles for each component at baseline. Convergent validity was assessed by correlation with related measures (e.g., physical activity, strength, general health, frailty), and predictive validity through area under the curve (AUC) analyses for adverse health outcomes at 3-years follow-up. Sex and age stratification was explored.

A total of 28,315 participants (51% female) were included for CPPB development. Scoring for the CPPB is the same for both sexes and for all ages, except for balance where different cut-offs are provided for those above/below 65 years of age. Convergent validity was in the predicted direction; however, the strength of the relationships was weak (<0.29) for all constructs. Scores on the CPPB showed good predictive validity for limitations in activities of daily living (AUC 0.82, 95%CI 0.81-0.84) and death (AUC 0.78, 95%CI 0.78-0.76) over 3 years. The CPPB is a promising new composite measure of mobility for middle-aged and older adults that predicts both disability and mortality.

Wearable high-density electromyography garment for automatic identification of ankle muscles in the clinic

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The accurate assessment of muscle activity during walking is essential for establishing optimal motor recovery strategies following neural injury. Surface electromyography (EMG) represents a non-invasive solution for accessing the activation patterns of leg muscles. However, its clinical adoption is hindered by the need for expert-driven electrode placement and muscle localization. Thus, current approaches are time-consuming and prone to variability, limiting their scalability in clinical settings. Therefore, the automatic identification of muscle-specific EMG signals is key for enabling personalized rehabilitation. To bridge this gap, we propose a wearable system comprised by a garment embedded with EMG electrodes and inertial measuring units (IMUs). This system is designed to eliminate the need for manual electrode placement in the clinic.
This method relies on IMU-based identification of gait cycles and the application of non-negative matrix factorization (NNMF) [1] for identifying the location of ankle dorsi- and plantar-flexor muscle cluster within the garment. Thereafter, the location of every muscle cluster is mapped over a three-dimensional leg model to locate the corresponding muscle. This approach was tested on 10 different garment orientations, each representing a rotation of 36 degrees relative to the previous position (*i.e.,* for a total of 360 degrees). For each orientation, we tested two walking speeds: comfortable and fast. Altogether, we show the potential of this approach for automatically identifying ankle muscles location via a sensorised garment. By facilitating consistent, user-independent access to muscle activation data, this method offers a scalable and portable solution for quantitative neuromuscular assessment in rehabilitation.

1. Simonetti et al. (2023) J Electromyogr Kinesiol. 2023 Oct;72:102808

P21: Tjeerd Boonstra

Age-related impairments in cognitive control during step initiation

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Older adults often experience impaired postural control, increasing their risk of falls. Age-related deficits in cognitive control may contribute by altering anticipatory postural adjustments (APAs) during step initiation. We investigated these effects by manipulating the probability of step initiation in a choice stepping Go/No-Go task and expected impaired APAs in older participants.

Twenty-four young (23 ± 3 years) and twenty-five older (72 ± 3.5 years) healthy adults stepped in response to a priming cue (stepping side) followed by an imperative cue (go or no-go). Go probability was set to 75% (mostly-go) or 25% (mostly-no-go), with 120 trials per condition. APA onset and movement onset were analysed using a Hierarchical Gaussian Filter (HGF) and correlated with intermuscular coherence (IMC) between muscle pairs.

Older participants showed longer reaction times, especially in the mostly-go condition, with a similar pattern for APA onset. Fitting the HGF to the behavioural data showed lower perceptual learning rates in older adults, indicating slower adaptation to changing trial probabilities. These rates were associated with differences in IMC, suggesting altered neural coupling during step preparation.

The reduced perceptual learning rates imply that older adults rely more on prior expectations and adapt more slowly to dynamic environments. These cognitive processing changes are reflected in APA timing and muscle coordination, underscoring the role of cognitive control in age-related differences in postural and gait function.

1. Mathys CD, Lomakina EI, Daunizeau J, Iglesias S, Brodersen KH, Friston KJ & Stephan K (2014). Front Hum Neurosci 8, 825.
2. Boonstra TW, Danna-Dos-Santos A, Xie HB, Roerdink M, Stins JF & Breakspear M (2015). Sci Rep 5, 17830.

P22: Conor Wall

Personalised gait retraining via CuePD: Use of a smartphone app to reduce fall risk

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People with Parkinson's disease (PwPD) often have impaired gait, including reduced stride length, slower gait speed, and increased variability, the latter being a key predictor of fall risk [1]. Rhythmic auditory cueing supports gait retraining, but current methods are often poorly designed i.e., unengaging and lack personalisation (to individual gait/music preference) [2]. CuePD is a smartphone app that provides gait assessment and personalised auditory cues using embedded inertial sensors. We hypothesised that personalised music cues (gait/preference) would yield greater gait improvements, be more engaging than metronome cues, and benefit a larger proportion of participants. Thirty PwPD (17M:13F, 68.9±6.0y) completed walking trials at baseline and with metronome (Me), instrumental music (IM), and vocal music (VM) cues set to +10% cadence. CuePD-derived gait characteristics were validated against a reference wearable (Opal, APDM) using intra-class correlation coefficients (ICC). Good to excellent agreements were found; mean metrics (ICC: 0.91–0.98 temporal, 0.85–0.92 spatial). VM cues led to the largest improvements: cadence increased by 6.91% (standardised response mean, SRM = 1.67), gait speed by 0.10m/s (SRM = 0.98), stride length by 5.3cm (SRM = 0.55), and stride time variability (coefficient of variation, CV%) decreased by 0.44% (SRM = -0.53). Usability was high (SUS = 85/100), and 93.3% preferred VM, describing it as more enjoyable and easier to follow. No association was found between musical sophistication and cueing response. CuePD is a valid, usable, and scalable tool for gait retraining, with personalised music cues offering a compelling alternative to traditional approaches.

[1] J. M. Hausdorff, M. E. Cudkowicz, R. Firtion, J. Y. Wei, and A. L. Goldberger, 'Gait variability and basal ganglia disorders: Stride-to-stride variations of gait cycle timing in parkinson's disease and Huntington's disease: GAIT VARIABILITY AND THE BASAL GANGLIA', *Mov. Disord.*, vol. 13, no. 3, pp. 428–437, May 1998, doi: 10.1002/mds.870130310.

[2] V. Cochen De Cock *et al.*, 'Rhythmic abilities and musical training in Parkinson's disease: do they help?', *npj Parkinson's Disease*, vol. 4, no. 1, p. 8, Mar. 2018, doi: 10.1038/s41531-018-0043-7.

The Role of the Primary Motor Cortex (M1) in Balance Skill Acquisition

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The role of the primary motor cortex (M1) in balance learning has increasingly been investigated in recent years. However, the role of M1 in balance skill acquisition remains unclear. This study aimed to investigate M1's involvement in balance learning. Thirty-four healthy participants were randomly assigned to a dual-task (DT) or control group. We hypothesized that balance learning would be hindered in the DT group, as previous research suggested that the cognitive tasks performed concurrently with motor tasks increase M1 inhibition and result in lower motor performance (1). All participants underwent a single session of balance training on a balance board equipped with a 3-axis accelerometer. The training consisted of five sets (S1 to S5) with three trials each. The DT group was instructed to count backward by 3s from a random number ranging from 300 to 900 to increase cognitive load, while the control group performed the training without additional tasks. We measured balance performance by calculating average tilt, average tilt velocity, and the coefficient of variation (CoV) of the tilt of the balance board. Balance learning was tested using mixed-design analysis of variance (ANOVA). The results showed that balance performance improved across all participants, as indicated by decreased average velocity and CoV (S1 to S5, $p=0.008$ and $p<0.0001$, respectively). While the control group showed further improvement after training, the DT group displayed no significant change in CoV ($p<0.0001$ and $p=0.127$, respectively). These findings may suggest that the cortex, likely M1, plays a role in balance skill acquisition.

1. McPhee AM, Cheung TC, Schmuckler MA. (2022). Dual-task interference as a function of varying motor and cognitive demands. Front. in Psychol., 13:952245.

P24: Arthur Fabre

Inertial Measurement Unit-based shoulder joint angles: accuracy assessment using OpenSense framework

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Introduction: Accurate measurement of shoulder joint range of motion is critical for motor impairment assessment, yet traditional clinical tools such as goniometers are often subjective, lack sensitivity, and capture limited motion [1]. Inertial Measurement Units (IMUs) can provide objective, continuous, and remote assessment of shoulder kinematics. However, challenges remain, including time-efficient workflows, precise sensor-to-segment calibration, and susceptibility to magnetic disturbances. OpenSense [2] offers a standardized framework for estimating joint angles from IMU data, including IMU-to-segment alignment and inverse kinematics. This study assessed the accuracy of shoulder joint angles derived from IMUs using the OpenSense framework against gold-standard skin-marker-based optoelectronic motion capture (OMC) inverse kinematics.
Methods: Twenty participants with normal shoulder function (age = 30.4 [6.0] years; 9 males) performed clinical and functional tasks. Kinematics of the thorax, clavicle, scapula, humerus, and forearm were simultaneously recorded with OMC and IMUs. IMUs were manually aligned with the body segments, and their orientations were estimated using a complementary filter. The Delft Shoulder and Elbow Model was used to compute IMU-based and OMC-based kinematics. Agreement was quantified using root mean square errors (RMSE) and consistency using correlation coefficient (CC).
Result: Highest accuracy was observed for glenohumeral elevation (CC = 0.81, RMSE = 4.86°) and elbow flexion/extension angles (CC = 0.86, RMSE = 7.70°). Glenohumeral axial rotation and elevation plane also showed strong correlations (>0.79) despite higher RMSEs (>12°). Acromioclavicular joints showed lower correlations (≈ 0.35-0.59) and higher RMSEs (5-10.2°), likely due to small motion ranges and soft tissue artefacts. Sternoclavicular joints demonstrated moderate agreement (5.07-10.92°).
Conclusion: The OpenSense workflow enables reasonably accurate estimation of primary shoulder and elbow joint angles and shows potential for low-cost 3D kinematic assessment. Lower accuracy for scapular and clavicular motions, as well as gimbal lock occurrences, highlight the need for further refinement of the framework for consistent and physiologically accurate outputs.

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1. Stefana E, et al., Sensors, vol. 21, 2021.
2. Al Borno M, J Neuroeng Rehabil, vol. 19, p. 22, 2022.

P25: Jasmine Menant

Lower limb muscle weakness and gait impairment in people with multiple sclerosis

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Aim: Our study aimed to establish the impact of lower limb muscle weakness on gait in people with multiple sclerosis (MS). We hypothesized that people with MS would have weaker lower limb muscles than controls and that, based on systematic review findings, reductions in hip extension during stance, knee flexion during swing, ankle dorsiflexion at initial contact and ankle plantar flexion at push off would be the strongest predictors of slow gait speed in people with MS [1].
Methods: 80 people with MS (mild to moderate disability, 30-76 years) and 44 healthy age and sex-matched controls undertook isometric maximal voluntary contractions at the ankle, knee and hip joints. Ankle contractures and lower limb kinematics during walking at self-selected speed were also recorded.
Results: Compared with controls, participants with MS had significant weakness in all lower limb muscle groups, displaying up to 50% less strength in knee extensors (mean difference (95%CI): 30.4 kg (23.7 to 37.1)). Within the MS sample, strength in all major muscle groups was significantly correlated with gait speed. Separate linear regression models identified the strongest predictors of slow walking speed ($p<0.001$) as: (i) weak knee extensors and hip abductors and, (2) smaller hip range of motion, reduced knee flexion in swing, increased knee flexion at foot strike and more severe ankle contracture.
Conclusions: Our findings partly confirm our hypotheses and will contribute to inform best practice guidance on training programs to improve walking and mobility in people with MS.

1. Coca-Tapia M, Cuesta-Gomez A, Molina-Rueda F and Carratala-Tejada, M (2021) Diagnostics 11, 584.