UNIVERSITY OF PÉCS

Doctoral School of Biology and Sport Biology

Neurokinematic regulatory mechanisms of the leg during one leg standing on unstable surfaces and during the pendulum test

Ph.D. thesis

Nyisztorné Mayer Petra

Supervisor:

Dr. Váczi Márk

habil. associate professor

Dr. Laczkó József

habil. associate professor

PÉCS, 2024

1. INTRODUCTION

My doctoral research focused on human movement, specifically on neurokinematic analyses of the lower limbs. During my research, I had the opportunity to thoroughly investigate two distinct areas that are interconnected within the themes of proprioception, sensory feedback, and motor coordination. As a result, my dissertation is structured into two main parts. Firstly, we examined the effects of a popular balance training device, the Togu Jumper, which provides an unstable surface. We assessed and compared the electrical activity of the lower limb muscles and the kinematic parameters of the balancing limb during single-leg balancing on both sides of the device, which have different properties. Secondly, we investigated the effects of body position, limb dominance, and the specific initiation of the test on lower limb muscle tone during the pendulum test in healthy individuals.

In recent years, several balance training devices have been developed such as soft mats, tilt boards, wobble boards, the both sides utilized Togu® Jumper® (TJ), and are used for the aforementioned purposes (Fitzgerald et al., 2010). Manufacturers provided TJs with a flat, solid plastic base and an inflatable bladder, corresponding to a halved Swiss ball (www.togu.de). Due to its unique design, TJ can be used as a compliant surface on the bladder side and a combination of a wobble board and a compliant surface on the flat side. Numerous studies reported the favorable effects of TJ exercises on postural control, balance, low back, or knee pain, and muscle strength. Despite the excessive data on the long-term effectiveness of TJ exercises, however, previous literature failed to extensively study whether the effects are surface-specific (Yaggie and Campbell 2006). Furthermore, exercising on a flat versus a bladder surface may induce different balancing strategies to maintain posture, and the kinematic and dynamic mechanisms of these strategies are unclear. Gruber et al., (2006) observed that, with a fixed ankle joint, the control of balance shifts from the shank to the thigh muscles. These conditions and the unique material and surface of the two sides of the TJ could lead to different progression of the balancing process on one leg. The closest to the focus of the present work is the study by Laudner and Koschnitzky (2010), in which they measured the electrical activity of the ankle muscles using a both sides utilized balance trainer, with the flat side either resting on the floor or facing up, and found no significant difference between the two conditions. To our knowledge, there have been no studies varying the two sides of the TJ and simultaneously monitoring leg muscle activation and kinematics around the ankle, knee, and hip joint. Understanding the neurokinematical strategies of balancing on the bladder versus the flat surface of the TJ is important in order to target stability in a specific joint.

The pendulum test was introduced by Wartenberg as a simple and reliable clinical test to objectively quantify quadriceps muscle tone in Parkinson's disease (Wartenberg, 1951). There is incoherence in the application of various initial body positions and starting mechanisms. Previous studies have used different body postures including upright, supine, and semi-supine (Brown et al. 1988). The semi-supine positions alternated between 15 and 70 degrees of hip flexion. Muscle spasticity is muscle length dependent, and the increase of muscle length augments the stretch reflex activity (Sheen, 2009), therefore the positioning of subjects during measurement could influence the results of the spasticity assessment, particularly when bi-articular muscles are involved. In our previous study, we also found, that the number of swings in the pendulum test performed in semi-supine position was significantly higher than in supine position in the case of a spinal cord-injured (SCI) person (Mayer et al., 2022). In contrast, others found that the position of the subject has no practical significance (Brown et al., 1988; de Azevedo et al., 2015; Ferreira et al., 2023). To the best of our knowledge, it has not been investigated how can leg dominance influence the spasticity of the muscles, while pendulum test is applied. Previous study showed that, greater quadriceps muscle volume is associated with higher levels of knee extensor muscle spasticity in children with spastic diplegic Cerebral Palsy (CP) (Pierce et al., 2012). In only a few studies were special apparatuses built to hold the limb magnetically (Lim et al, 2006; Winter 2009) or by a light strap around the ankle (Stein et al., 1996) for the opportunity to release the leg abruptly and make the assessment more objective. In these studies, they did not compare the automatic releasing mechanisms to the usually used hand release.

2. OBJECTIVES

Understanding the precise effects of balance devices that are experientially similar in difficulty but have different properties on the lower limbs can make the use of these devices more specific and effective. Due to the differing properties of the two sides of the Togu Jumper (TJ), we hypothesized that single-leg standing on these surfaces would require different balancing strategies, potentially exerting different effects on various regions of the lower limb. To our knowledge, no previous studies have simultaneously examined the electrical activity of the lower limb muscles and the kinematics of the limb segments around the ankle, knee, and hip joints while balancing on both sides of the TJ. Based on this, our objectives were as follows:

- To examine and compare the electrical activity of the lower limb muscles on three different surfaces: flat ground, the bladder side of the TJ, and the flat side of the TJ during single-leg balancing.
- To investigate the linear acceleration of the lower limb segments (foot, lower leg, thigh, pelvis) on the three surfaces: flat ground, the bladder side of the TJ, and the flat side of the TJ during single-leg balancing.
- To examine the segmental angular changes of the lower limb segments (foot, lower leg, thigh, pelvis) on the three surfaces: flat ground, the bladder side of the TJ, and the flat side of the TJ during single-leg balancing.

Regarding the pendulum test, we hypothesized that due to different rectus femoris muscle lengths, varying use of dominant and non-dominant limbs, and differences in initiation methods, we would observe significant differences in the pendulum test parameters across the tested conditions. With this in mind, our objectives were as follows:

- To examine and compare the swinging parameters of the lower leg during the pendulum test in young, healthy individuals in both supine and semi-sitting positions.
- To investigate and compare the swinging parameters of the dominant and non-dominant lower limbs during the pendulum test.
- To examine the swinging parameters of the lower leg during the pendulum test using traditional manual initiation and automatic initiation methods.

3. METHODS

Single-leg Balancing on Both Sides of the Togu Jumper

In our study, 14 healthy female university students participated voluntarily, with an average age of 23.6 ± 1.9 years. The participants were required to balance on their dominant lower limb on three different surfaces: flat ground, the bladder side of the TJ, and the flat side of the TJ. All participants first performed the balancing task on flat ground, followed by alternating trials on the two sides of the TJ in a random order. The balancing trials lasted for 10 seconds each (Laudner and Koschnitzky, 2010).

During the balancing tasks, the electrical activity of the lower limb muscles was collected telemetrically. Surface electrodes were placed on eight lower limb muscles: tibialis anterior (TA), peroneus longus (PL), soleus (SOL), gastrocnemius medialis (GastM), biceps femoris (BF), vastus lateralis (VL), vastus medialis (VM), and gluteus medius (GM).

Balancing ability on the three surfaces was quantified using the segmental sway method (Curtis et al., 2015; Ivusza et al., 2022). Inertial measurement units (Noraxon U.S.A. Inc., Scottsdale, United States) were attached to the foot, lower leg, thigh, and pelvis segments. The sensors are equipped with three orthogonal gyroscopes capable of detecting angular displacement and angular velocity. These allowed us to determine the angular deviation from the vertical axis (orientation angle) in the selected plane. The vertical axis (0˚) was calibrated during a 10-second period when the participants stood straight with feet together. The placement of the sensors and the calibration process followed the manufacturer's recommendations. The sensors were attached to the limb segments.

Raw EMG signals were collected at a frequency of 2000 Hz, filtered (20-500 Hz), and then smoothed using the root mean square (RMS) method with a 50 ms moving window. Finally, the average processed EMG of each muscle was calculated for the entire 10-second balancing period.

During the test, we recorded segmental orientation angles and linear acceleration data over time in both the frontal and sagittal planes using the Noraxon MyoMotion system (Noraxon U.S.A. Inc., Scottsdale, United States) at a data collection frequency of 100 Hz. All EMG and kinematic data were synchronized and processed using myoRESEARCH 3.18

software. The averages of three balancing trials performed on the three different surfaces were used for statistical analysis.

For statistical analysis, means and standard deviations were calculated for the measured and computed variables. All data were checked for normality using the Shapiro-Wilk test. Relative EMG activity of the muscles across different conditions (surfaces) was compared using a two-way ANOVA, with muscle (TA, PL, SOL, GastM, VL, VM, BF, GM) and surface (flat ground, TJ bladder side, and TJ flat side) as independent variables. Interactions between conditions (flat ground, TJ bladder side, and TJ flat side) and body segments (foot, lower leg, thigh, and pelvis) were examined using two-way ANOVA for linear acceleration and segmental sway data recorded in the frontal and sagittal planes during the 10-second balancing trials. Bonferroni correction was applied for all pairwise comparisons, and statistical significance was set at $p = 0.05$.

Measuring Muscle Tone Using the Pendulum Test

Our study included 15 healthy young adults (9 males, 6 females) aged 18-32 years. We used a Zebris 3D ultrasound-based motion analysis system (ZEBRIS, CMS10, Medizintechnik GmbH, Isny, Germany), which is capable of simultaneously recording muscle activity and kinematic data on 8 channels.

We placed four Zebris markers on the lateral side of each limb: at the malleolus lateralis, the fibula head, the lateral femoral epicondyle, and the greater trochanter. Surface electrodes were placed on four thigh muscles in positions recommended by SENIAM (www.seniam.org): vastus lateralis, vastus medialis, rectus femoris, and biceps femoris. The test was performed in eight conditions, varying by two initiation methods (a, b), two body positions (supine and semi-sitting), and the dominant and non-dominant limbs.

a) **Manual initiation:** The examiner holds the participant’s ankle, elevates the lower leg to fully extend the knee joint, without lifting the limb from the examination table. The participant is instructed to relax completely, and then the examiner unexpectedly releases the limb, allowing it to swing freely.

b) **Automatic initiation:** The participant’s ankle rests on a foot support wooden board (38 cm x 34 cm), connected to a stable table by hinges. The knee joint is fully extended, and the thigh rests on the examination table. When the foot support is closed, a strong electromagnet holds it in a horizontal position. After muscle relaxation, the examiner sends a ready signal to the control unit, which randomly disengages the electromagnet after 5-15 seconds, causing the foot support to drop unexpectedly and initiating the test (Figure 1).

The central measurement unit collected kinematic marker data at a sampling frequency of 50 Hz, which were processed using custom-developed MATLAB and Python software. Knee flexion angles were calculated using trigonometric equations. The Relaxation Index (RI) expresses the ratio of the first knee flexion angle to the difference between the initial flexion angle and the final (resting) angle (Bajd and Vodovnik, 1984). According to several studies, the index reliably indicates spasticity (Brown et al., 1988).

For statistical analysis, we used SPSS Statistics (Version 29) software. Data normality was checked with the Shapiro-Wilk test. Paired t-tests were applied to data sets with normal distribution ($p>0.05$), and Wilcoxon tests were used for non-normally distributed data sets ($p\leq0.05$). We compared data between the two test positions, the dominant and non-dominant limbs, and the two test initiation methods. The significance level was set at $p=0.05$.

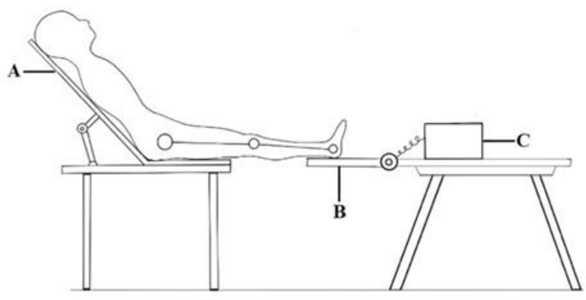

Figure 1. *Experimental setup for pendulum test with automata foot-releasing apparatus*

A: adjustable backrest in 45 degrees semi-supine position, B: plate with electromagnet, C control unit

4. RESULTS

One leg balancing on the Togu Jumper

EMG: In EMG activity, there was significant main effect for surface ($F = 123.69$, $p < 0.001$) and muscle ($F = 69.87$, $p < 0.001$) with surface by muscle interaction ($F = 13.18$, $p < 0.001$). The post-hoc test of the main effect revealed that EMG activity was higher during balancing on either TJ side versus the floor ($p < 0.001$), when all muscle activites were pooled within a condition, but there was no difference between the bladder vs. the flat side of the TJ ($p = 0.230$). The post hoc test of the surface by muscle interaction revealed that GM and GastM muscle activities were uniform across the three conditions, and SOL activity was greater in the bladder vs. floor conditon ($p = 0.009$). All other muscles showed greater activity in either TJ condition vs floor, but there were no differences between the bladder and the flat TJ conditons (Figure 2.).

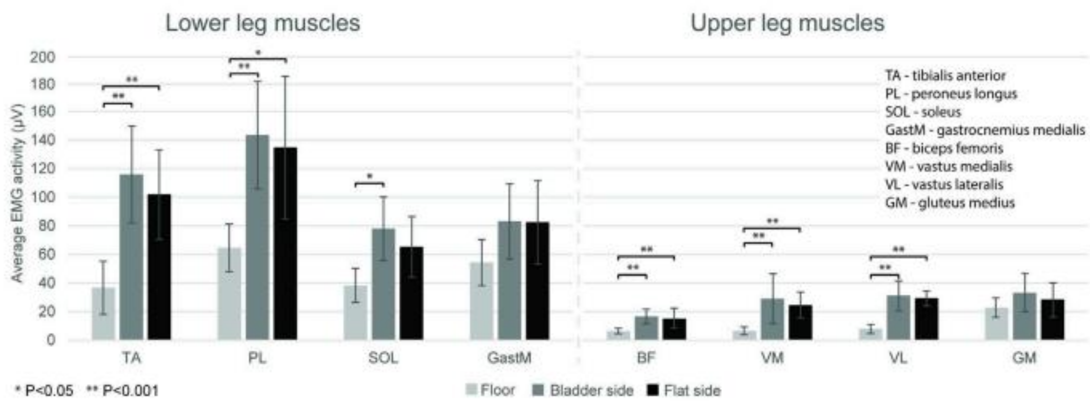

*Figure 2. Average EMG activity (mean ± SD) in the three conditions (floor, and bladder and flat side of the Togu Jumper) for lower and upper leg muscles during the 10-s single leg balance trials. Horizontal bars indicate statistically significant differences *($p < 0.05$) and ** ($p < 0.001$).*

Linear acceleration: Results of the statistical analysis declared main effects for surface in frontal plane ($F = 72.38$, $p < 0.001$) and sagittal plane ($F = 107.47$, $p < 0.001$), main effects for segment in frontal plane ($F = 43.37$, $p < 0.001$) and in sagittal plane ($F = 24.11$, $p < 0.001$), furthermore a significant surface by segment interaction both in frontal plane ($F = 30.17$, $p < 0.001$) and in sagittal plane ($F = 17.64$, $p < 0.001$). The post-hoc test revealed that in both planes foot acceleration was different among the three conditions ($p < 0.001$): in sagittal plane, the greatest was in the bladder, and the smallest was in the floor condition. In the frontal plane, the greatest was in the flat, and the smallest was in the floor condition. In case of the shank and the thigh segments, in both planes, both TJ conditions revealed higher accelerations, compared to the floor, but there was no difference betweeen the bladder and the flat TJ condtions. No difference was found among the three conditions in the acceleration values of the pelvis in both planes (all p > 0.05)(Figure 3.).

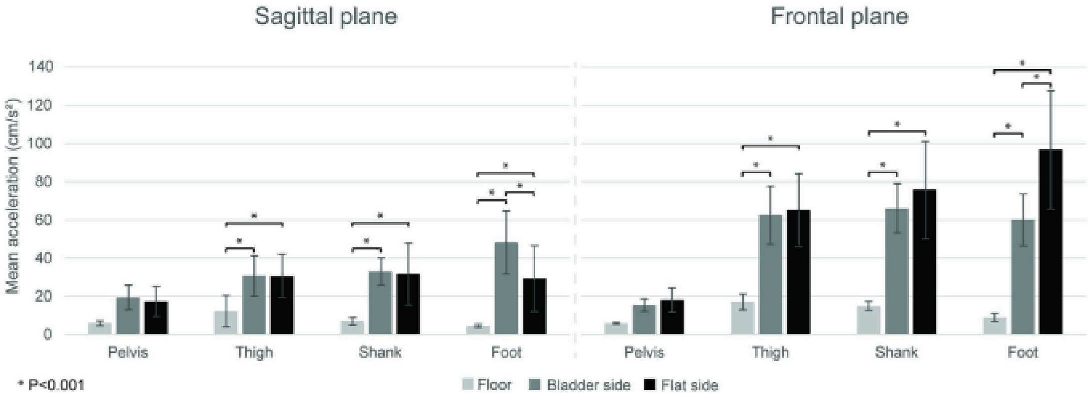

Figure 3. Average linear acceleration (mean ± SD) in the three conditions (floor, and bladder and flat side of the Togu Jumper) for the leg segments (pelvis, thigh, shank, foot) in frontal and sagittal plane. Horizontal bars indicate significant differences (p < 0.001)

Segmental angular sway: We found significant main effect for surface in both planes (frontal: F = 66.92, p < 0.001; sagittal: F = 20.01, p < .001), as well as significant surface by segment interactions (frontal: F = 51.54, p < 0.001; sagittal plane: F = 5.12, p = 0.030). In the case of the foot, in frontal plane, the post-hoc tests revealed significant differences among the three conditions (p < 0.001); in sagittal plane segmental angular sway was higher during balancing on the bladder side vs. the two other conditions (p < 0.001) and there was no significant difference between floor and flat side (p = 0.260). No difference was found among the three conditions in the case of the shank, thigh, and pelvis in either plane (all p > 0.05).

Measurement of muscle tone with the pendulum test

Number of swings

Comparing the number of swings in semi-supine versus supine positions, in investigator-release mode, there were marginally significant differences, meaning a slightly bigger number of swings in semi-supine position (p=0.06, p=0.07). In automata-release mode, the number of swings was significantly higher in semi-supine than in supine positions, in the case of the non-dominant leg ($p=0.03$). This indicates higher muscle tone in supine position.

Comparing the number of swings in the dominant leg versus the non-dominant leg, it was found that the non-dominant leg had significantly more swings with automatic-release mode in both body positions ($p=0.009$, $p<0.001$) and also in hand-release mode in supine body position ($p<0.001$). This indicates higher muscle tone in the dominant leg.

Comparing the number of swings in investigator-release mode versus automatic-release mode, there were no significant differences in either test condition.

Relaxation index

Comparing the relaxation index obtained in semi-supine versus supine positions the RI values were similar in the case of investigator-release mode and RI was significantly smaller in supine than in semi-supine position when automata-release mode was applied ($p=0.005$, $p<0.001$). This indicates higher muscle tone in supine position.

Comparing the relaxation index in the dominant leg versus the non-dominant leg, the RI was significantly smaller for the non-dominant leg in both release modes and positions ($p=0.02$, 0.01, 0.02, 0.04). This indicates a higher muscle spasm in the non-dominant leg.

There were contradicting results comparing the relaxation index in investigator-release mode versus automata-release mode. In supine position the index was higher in investigator-release mode, but lower in automata-release mode, significantly on the non-dominant side ($p=0.01$). Thus, assessment in supine position with automata-release mode suggested higher muscle tone than in investigator-release mode. This was not the case in a semi-supine position, and the RI was significantly higher on the non-dominant side ($p=0.009$).

5. SUMMARY

Single-leg stance on the two sides of the Togu Jumper

In my dissertation, I showed the changes in leg muscle activity and kinematics in response to a single-leg stance on the two sides of the Togu Jumper and the floor. Except gluteus medius and gastrocnemius medialis, all muscles were more active when balancing on either Togu Jumper side compared to the floor, but there was no difference between the two sides in any muscles. Furthermore I showed, that the linear acceleration was the greatest in the frontal plane on the flat Togu side in the case of the foot. Pelvis acceleration was unaffected by the balance conditions. Segmental angular sway was the greatest in the frontal plane, on the bladder side in the foot segment. No difference was found among the three conditions in the case of the shank, thigh, and pelvis. From these, I concluded that the use of the two Togu Jumper sides produced different balance strategies in the foot segment and induced no difference in equilibrium procedures at the level of the pelvis.

Muscle tone assesment by pendulum test

In my dissertation, I showed the effect of body position, leg dominance, and automatic releasing mechanism on quadriceps muscle tone assessed by the Wartenberg pendulum test in able-bodied persons. Applying automata-release mode, in the non-dominant leg the number of swings was significantly higher in semi-supine than in supine position. The non-dominant leg had significantly more swings with automata-release mode than with investigator-release mode in both body positions. In investigator-release mode this occurred in supine position. Regarding the number of swings in investigator-release versus automata-release mode, no significant differences were found in any test condition. Furthermore, I have shown that in automata-release mode, in the non-dominant leg the relaxation index was significantly higher in semi-supine than in supine position. The relaxation index showed significant difference between the investigator-release and automata-release mode for the non-dominant leg. The values of the relaxation index didn't support in all test conditions the results what the number of swings provided about the muscle tone. In automata-release mode the dominant leg has lower number of swings, and higher relaxation index than the non-dominant leg. From these, I can conclude, that the effect of body position on the quadriceps muscle tone can be assessed applying the pendulum test with an automatic leg releasing mechanism even when the application of conventional investigator-release mode does not show significant effect. The pendulum test is more sensitive to assess spasticity with automatic-release than with investigator-release mode.

6. REFERENCES

Brown RA, Lawson DA, Leslie GC, Part NJ. Observations on the applicability of the Wartenberg pendulum test to healthy, elderly subjects. *Journal of Neurology, Neurosurgery & Psychiatry* 1988;51(9), 1171-1177. https://doi.org/10.1136/jnnp.51.9.1171

de Azevedo ER, Maria RM, Alonso KC, Cliquet Jr A. (2015) Posture influence on the pendulum test of spasticity in patients with spinal cord injury. *Artificial organs*;39(12), 1033-1037. https://doi.org/10.1111/aor.12500

Ferreira DM, Liang H, Wu J. (2023) Effect of body position and external ankle load on the pendulum test in adults. *The Knee*; 42, 99-106. https://doi.org/10.1016/j.knee.2023.03.006

Fitzgerald, D., Trakarnratanakul, N., Smyth, B., and Caulfield, B. (2010). Effects of a wobble board-based therapeutic exergaming system for balance training on dynamic postural stability and intrinsic motivation levels. J. Orthop. sports Phys. Ther. 40, 11–19. doi:10.2519/jospt.2010.3121

Gruber, M., Bruhn, S., & Gollhofer, A. (2005). Specific adaptations of neuromuscular control and knee joint stiffness following sensorimotor training. *International journal of sports medicine*, 636-641.

Laudner KG, Koschnitzky MM (2010) Ankle muscle activation when using the Both Sides Utilized (BOSU) balance trainer. *The Journal of Strength and Conditioning Research* 24:218-222. doi: 10.1519/JSC.0b013e3181c490d4

Lim HK, Cho KH, Kim BO, Lee YS. (2006) Pendulum Test and Parameters for Quantitative Evaluation of Spasticity. *Key Engineering Materials*;326, 859-862. https://doi.org/10.4028/www.scientific.net/KEM.326-328.859

Pierce SR, Prosser LA, Lee SC, Lauer RT. (2012) The relationship between spasticity and muscle volume of the knee extensors in children with cerebral palsy. Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association;24(2), 177. https://doi.org/10.1097/PEP.0b013e31824cc0a9

Sheean, G. (2002). The pathophysiology of spasticity. *European journal of neurology*, *9*, 3-9.

Stein RB, Zehr EP, Lebiedowska MK., Popovic DB, Scheiner A, Chizeck HJ. (1996) Estimating mechanical parameters of leg segments in individuals with and without physical disabilities. *IEEE Transactions on Rehabilitation Engineering* ;4(3), 201-211. https://doi.org/10.1109/86.536776

Yaggie, J. A., and Campbell, B. M. (2006). Effects of balance training on selected skills. J. Strength Cond. Res. 20, 422–428. doi:10.1519/R-17294.1

Winter DA. (2009) Biomechanics and motor control of human movement. John Wiley & sons;97-98.
https://doi.org/10.1002/9780470549148.ch5

7. OWN PUBLICATIONS

PUBLICATIONS RELATED TO THE THESIS:

Mayer P, Sebesi B, Vadász K, Laczkó J, Zentai N, Balázs B, Váczi M. (2023) Kinematics and muscle activity of the lower limb during single-leg stance on the two sides of the Togu Jumper FRONTIERS IN PHYSIOLOGY 14 Paper: 1049035 , 9 p. **(Q1; IF: 4,755)**

Mayer P, Bodor A, Szabó D, Laczkó J, Zentai N. (2024) The effect of body position, leg dominance, and automatic releasing mechanism on quadriceps muscle tone assessed by Pendulum Test in able-bodied persons IDEGGYÓGYÁSZATI SZEMLE-Clinical Neuroscience (elfogadva, szerkesztés alatt) **(Q4; IF: 0,9)**

CONFERENCE ABSRTACTS RELATED TO THE THESIS:

Mayer, P., Vass, L., & Váczi, M. (2019). KINEMATICS AND MUSCLEACTIVITY OF THE LOWER LIMB DURING ONE LEG STAND ON DIFFERENT SURFACES (PILOT STUDY). In 24th Annual Congress of the EUROPEAN COLLEGE OF SPORT SCIENCE - BOOK OF ABSTRACTS (pp. 649–650).

Mayer P, Sebesi B, Balázs B, Vadász K, Vass L, Laczkó J, Váczi M. (2021) Alsó végtagi izomaktivitás és kinematika vizsgálata instabil felületen végzett egyensúlyozás közben MAGYAR SPORTTUDOMÁNYI SZEMLE 22. : 91(3) pp. 82-82. , 1 p.

Mayer P, Zentai N, Mravcsik M, Bartok H, Radeleczki B, Laczko J. (2022) The effect of body position on the spasticity of quadriceps muscle after spinal cord injury. Program No. 303.15 Neuroscience Meeting Planner. San Diego, CA: Society for Neuroscience; Online

Mayer, P., Bartók, H., Zentai, N., Radeleczki, B., & Mravcsik, M. (2022). Spaszticitás mérése mozgásanalizáló készülékkel éptestű és gerincvelősérült személyeknél. REHABILITÁCIÓ: A MAGYAR REHABILITÁCIÓS TÁRSASÁG FOLYÓIRATA, 32(3), 49.

Mayer, P., Bodor, A., Laczkó, J., & Zentai, N. (2023). Spaszticitás Pendulum teszttel való mérésének függése a testhelyzettől és a teszt indításának módjától. REHABILITÁCIÓ: A MAGYAR REHABILITÁCIÓS TÁRSASÁG FOLYÓIRATA, 33(2–3.), 55–55.

Mayer, P., Bodor, A., Laczkó, J., Szabó, D., & Zentai, N. (2024). A testhelyzet, a végtagdominancia és a pendulum teszt speciális indításainak hatása az alsó végtag izomtónusára. MAGYAR SPORTTUDOMÁNYI SZEMLE, 25(108), 82–82.

Mayer P, Zentai N, Bodor A, Laczko J. (2024): Comparison of investigator-release and automata-release mechanisms when applying Pendulum Test to assess quadriceps muscle tone in able bodied persons. Accepted for presentation at Neuroscience 2024, Annual Meeting of the Society for Neuroscience, taking place October 5, In Chicago, IL, USA

OTHER PUBLICATIONS:

Váczi M, **Nyisztorné Mayer P**, Vass L, Vadász K, Pozsgai M, Sebesi B, Meszler B, Atlasz T. (2018) Térdízületet stabilizáló izmok erejének és aktivitásának szerepe unilaterális felugrásnál és leérkezésnél MAGYAR SPORTTUDOMÁNYI SZEMLE 19 : 75(3) pp. 94-94. , 1 p.

Varga M, **Nyisztorné Mayer P**, Vass L, Vadász K, Sebesi B, Meszler B, Atlasz T, Váczi M. (2018) Térdízületi és medencestabilizáció frontális síkú neurokinematikai mechanizmusai unilateralis felugrásnál MAGYAR SPORTTUDOMÁNYI SZEMLE 19 : 77(5) pp. 78-78. , 1p.

Sebesi B, **Mayer P**, Vass L, Vadász K, Varga M, Meszler B, Atlasz T, Váczi M. (2018) The role of hip joint abductors in stabilizing the knee joint during unilateral jumping and unilateral landing on unstable surface.

Sebesi B, **Nyisztorné Mayer P**, Vass L, Vadász K, Varga M, Meszler B, Atlasz T, Váczi M. (2018) Térdízületi stabilizáció unilaterális felugrásnál és instabil leérkezésnél Konferencia helye, ideje: Budapest, Magyarország 2018.12.07. - 2018.12.08. Budapest: Magyar Sporttudományi Társaság,

Sebesi B, **Mayer P**, Vass L, Vadász K, Varga M, Meszler B, Atlasz T, Váczi M. (2019) The role of gluteus medius muscle in stabilizing the knee joint during jumping and landing on nstable surface In: Proceedings of Global Congress on Physiotherapy, Physical rehabilitation & Sports Medicine 2019-04-22-24. [Dubai, Egyesült Arab Emírségek] pp. 55-55. , 1 p.

Varga M, Atlasz T, Vadász K, Vass L, Meszler B, **Mayer P**, Sebesi B, Váczi M. (2019) Frontal plane neurokinematical mechanisms of knee joint and pelvis stabilization during unilateral vertical jump In: Proceedings of Global Congress on Physiotherapy, Physical rehabilitation & Sports Medicine 2019-04-22-24. [Dubai, Egyesült Arab Emírségek] pp. 56-56. , 1 p.

Sebesi B, **Nyisztorné Mayer P**, Vass L, Vadász K, Varga M, Meszler B, Atlasz T, Váczi M.(2019) The role of hip joint abductors in stabilizing the knee joint during unilateral jumping and unilateral landing on unstable surface In: Csiszár, Beáta; Bódog, Ferenc (szerk.) Medical Conference for PhD Students and Experts of Clinical Sciences : Book of abstracts Pécs, Magyarország : Pécsi Tudományegyetem Doktorandusz Önkormányzat, 87 p. p. 25

Vadász K, **Nyisztorné Mayer P**, Vass L, Varga M, Sebesi B, Meszler B, Atlasz T, Váczi M.(2019) Medenceövi izmok aktivitása unilaterális felugrásnál In: IV. Sporttudományi PhD Szimpózium : Program- és absztrakfüzet p. 58 , 58 p.

Sebesi B, **Nyisztorné Mayer P**, Vass L, Vadász K, Varga M, Meszler B, Atlasz T, Váczi M. (2020) A térdízület direkt és indirekt stabilizációjának biomechanikai vizsgálata = Direct and indirect stabilization mechanisms in the knee joint In: Prisztóka, Gyöngyvér; Pfefferkorn, Laura-Jane; Kertai, Bendegúz (szerk.) XVIII. Szentágothai János Multidiszciplináris Konferencia és Hallgatói Verseny Absztrakt kötet XVIII. János Szentágothai Multidisciplinary Conference and Student Competition Book of Abstracts Pécs, Magyarország : János Szentágothai Scholastic Honorary Society, Faculty of Sciences, University of Pécs 187 p. pp. 173-174. , 2 p.

Varga M, Atlasz T, Vadász K, Vass L, Meszler B, **Mayer P**, Sebesi B, Váczi M. (2020)Összefüggés a gluteus medius aktivitása és a térd valgus között unilaterális felugrással = Association between gluteus medius activity and knee valgus during unilateral vertical jumpIn: Prisztóka, Gyöngyvér; Pfefferkorn, Laura-Jane; Kertai, Bendegúz (szerk.) XVIII. Szentágothai János Multidiszciplináris Konferencia és Hallgatói Verseny Absztrakt kötet XVIII. János Szentágothai Multidisciplinary Conference and Student Competition Book of Abstracts Pécs: János Szentágothai Scholastic Honorary Society, Faculty of Sciences, University of Pécs 187p. pp 175-177. , 2 p.

Vadász K, **Nyisztorné Mayer P**, Varga M, Sebesi B, Váczi M. (2021) Medenceövi izmokban mért neurokinematikai mechanizmusok unilaterális felugrásnál MAGYAR SPORTTUDOMÁNYI SZEMLE 22. : 91(3) pp. 121-121. , 1 p.

Szabó, D., Kiss, G., Tékus, E., **Mayer, P.**, Váczi, M., Fekete, J. D., … Mintál, T. (2024). Therapeutic Effectiveness of Postural Treatment on Youth Swimmers' Anterior Shoulder Pain—An Interventional Study. APPLIED SCIENCES-BASEL, 14(4). http://doi.org/10.3390/app14041486

OTHER CONFERENCE ABSTRACTS:

Nyisztorné, M. P., Vass, L., & Váczi, M. (2018). Lábszárizmok erejének, aktivitásának és a boka propriocepciójának vizsgálata bokaszalag sérülteknél a sportrehabilitáció kezdetén. MAGYAR SPORTTUDOMÁNYI SZEMLE, 19(3(75)), 71–72.

Mayer, P., & Vass, L. (2019). Hosszú távú, gyalogos zarándoklatok testmozgást befolyásoló hatásai. MAGYAR SPORTTUDOMÁNYI SZEMLE, 20(2(79)), 63.

Vadász K, **Nyisztorné Mayer P**, Vass L, Varga M, Sebesi B, Meszler B, Atlasz T, Váczi M. (2019) Gluteus medius, quadratus lumborum és erector spinae izmok aktivitása különböző terhelésű függőleges felugrási kondíciók alatt In: XVI. János Szentágothai Multidisciplinary Conference and Student Competition – Abstracts. Pécs, Magyarország : János Szentágothai Scholastic Honorary Society, Faculty of Sciences, University of Pécs, pp. 212-212. , 1 p

Vadász K, **Nyisztorné Mayer P**, Vass L, Varga M, Sebesi B, Meszler B, Atlasz T, Váczi M.(2019) Gluteus medius, quadratus lumbroum, and erector spinae muscle activity during vertical jump with various loads In: Bunc, V.; Tsolakidis, E. (szerk.) 24th Annual Congress of the european college of sport science - book of abstracts. Köln, Németország : European College of Sport Science, pp. 29-29. , 1 p.