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THE ACUTE EFFECT OF PERCUSSIVE THERAPY ON POSTURAL STABILITY AND MUSCLES ACTIVATION IN PEOPLE WITH CHRONIC ANKLE INSTABILITY AND CONTROLS

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ABSTRACT

Title: THE ACUTE EFFECT OF PERCUSSIVE THERAPY ON POSTURAL STABILITY AND MUSCLES ACTIVATION IN PEOPLE WITH CHRONIC ANKLE INSTABILITY AND CONTROLS

Subjects: In recent years, the percussive therapy technique, and its associated massage guns (TheraGun^{TM}) have appeared on the massage market. This relatively easily accessible form of self-massage was associated with soft tissue relaxation, improved range of motion, and direct activation of the massaged muscles before or after physical activity. Muscle tightness has been related to postural instability and higher risk of lower limb injuries. However, there is still lack of evidence about effects of percussive therapy on postural stability and muscle activation in people within various musculoskeletal conditions, like chronic ankle instability (CAI), where postural stability and movement initiation may be compromised. With each distortion or luxation of the ankle, the possibility of re-occurrence of this type of injury increases, as well as associated complications such as absence from the training process or disruption of normal stereotypes. Among other things, chronic ankle instability can be a compelling reason for the absence of physical activities, to which many health-maintaining factors are linked. Therefore, this project aims to examine the effect of percussive therapy on postural stability and muscle activation during static and dynamic movement in subjects with the history of CAI and without.

Methods: The project was implemented as a single-blinded randomized controlled trial. The number of participants was determined using a power analysis with a predicted medium effect size - F2 = 0.15; with a significance level of α = 0.05 and a test power of 1-β = 0.8) to (n=44). Intentional allocation of participants into 2 groups (Group 1 – n=10 CAI YES / n= 11 CAI NO; Group 2- n=10 HEALTHY YES / n=11 HEALTHY NO). Initial measurements of 30 s postural stability test on pressure platform FootScan (FS) before and after (non)TheraGun application in standing on both legs with open eyes (OE), on both legs with eyes closed (CE), Flamingo stand on the dominant (DOM) lower limb (FL_{DOM}) and the non-dominant (NON) lower limb (FL_{NON}). This was followed by total of 4 trials of individual heel raises (6s data collection on FS during heel rise, 10 seconds rest between trials). Electromyographical (EMG) activity in the calf region was

simultaneously recorded in all performed tests. EMG sensors were attached to the m. gastrocnemius vastus lateralis during the first test and remained affixed to the skin for the second test. Consequently, followed by a 1:30min pause – massage (the 30s each m. triceps surae) with TheraGun^{TM}. The same principle was followed for the control groups except for the TheraGun^{TM} massage part.

Results: Primary statistical analysis before PT treatment found significant difference ($p=0.014$) in the EMG parameter of bilateral asymmetry between dominant and non-dominant lower limb during heel rise performance between HEALTHY and CAI groups (32.94±19.93 % vs. 48.07±28.08 %). No other difference in selected parameters was found before PT treatment.

Within experiment protocol and comparison between pre and post-tests in postural stability, we found significant differences ($p<0.05$) in OE tests mainly between the HEALTHY and CAI groups. Specifically, post-hoc analysis revealed significant difference ($p=0.014$) between CAI NO PRE (CNP) and HEALTHY YES POST (HYPO) and between the CAI NO POST (CNPO) vs. HYPO ($p=0.05$). The only statistical difference ($p=0.045$) within CAI group was found in CNP vs. CAI YES POST (CYPO). Since there was no significant difference in the pre-tests between any of the groups (CNP and CYP), we may confirm the hypothesis of the effect of PT in postural stability (OE) test.

In contrast, in the CE test, this change was observed between groups CNPO and CYPO ($p=0.05$). Since there was no pre-test difference between the CAI groups in CE parameter, we may also confirm the effect of PT in CE test, even though the intragroup outcomes between pre and post-test weren't sensitive enough to find significant ($p<0.05$) improvement.

Unilateral postural stability surveyed in relation to PT showed increased bilateral asymmetry between DOM and NON in Flamingo test (expressed as %). Especially HYPO group revealed risen asymmetry after PT when compared to CNPO ($p=0.007$), CNP ($p=0.015$) and CYPO ($p=0.05$). Key finding was measured significant difference in intragroup parameter between HYP vs. HYPO ($p=0.014$), which confirmed increased bilateral asymmetry in unilateral postural stability HEALTHY subjects before and after use of PT, but not in CAI.

In terms of muscle activation (sEMG), we found increased bilateral asymmetry during OE (DOM vs NON %) between the CYPO and CNP ($p=0.041$),

with risen asymmetry during OE in group using PT (72.52%) than in group without PT in pre-test (47.94%). However, both CAI groups showed risen asymmetry in post-test, while only PT group (CYPO) showed significant difference from CNP. Thus, there is low indication that PT could increase muscle activation asymmetry in CAI during static postural stability.

In muscle activation during heel rise in DOM, we found lowered EMG activation after PT use in the CYPO group when compared to HYPO ($p=0.026$) and HYP ($p=0.026$). HEALTHY groups showed no change ($p>0.05$) before or after PT (or no PT) use. However, CAI group without PT during pre-test showed almost significant difference ($p=0.067$) when compared to CAI group with PT in post-test (121.77 ± 58.16 $\%RMS_{max}$ vs. 79.66 ± 35.64 $\%RMS_{max}$). This indicate that CAI subjects may have got lower muscle activation in the DOM during movement after PT use.

In terms of bilateral asymmetry of muscle activation during heel rise, the significantly higher asymmetry was found in CAI group after PT use (approximately 66%) when compared to HYPO (18%) ($p=0.008$) and HYP (26%) ($p=0.025$). Conversely, HEALTHY group after PT use showed lower asymmetry (18%) during heel rise when compared to CNPO (54%) ($p=0.043$) and HEALTHY group without PT use in post-test (HNPO; 54%) ($p=0.044$), but HEALTHY groups did not differ in pre-test.

Conclusion: The aim of this master thesis was to examine the acute effect of percussive therapy on the postural stability and muscle activation in subject with and without CAI. The analysis showed high variance within individual results, thus high standard deviations across the study. Nevertheless, we found significant differences between the analyzed groups before and after the application of percussive therapy. However, not all results showed clear indications of therapy effect in terms of intragroup (pre vs. post-test within same groups). It seems, that there exist differences between CAI and non-CAI subjects, and also that PT may affect postural stability and muscle activation in both groups with different outcomes. Results indicated, that within dynamic movement performance, PT may affect HEALTHY subject positively in terms of lowering bilateral asymmetry, while negatively in CAI, by rising the difference between dominant and non-dominant lower limb muscle activation in calf area. Conversely, positive effect of

percussive therapy on static postural stability in CAI subjects was found, with improvement in the group using PT in close stand tests with or without open eyes. Other observed parameters such as postural stability changes during unilateral stand or muscle activation did not show clear significant changes in patients with CAI who used PT. Thus, it seems from our results, that a significant change after PT use in people with CAI affect static and dynamic performance differently. Besides lower homogenous participants number and only one analyzed muscle part within calf area, we are aware of study limitations within unclear results and high individual differences. However, increased motor strategies required for unilateral standing and dynamic movements may affect the results, regardless of percussion therapy. Thus, more sensitive testing procedures in the calf area in larger homogenous population is recommended in the future research, while more dynamic movements could be analyzed. These results should add to the knowledge about the percussive therapy used in CAI population and its use within postural stability control pre-activation.

Keywords: Lateral Gastrocnemius; Electromyography; Muscle Activation; Heel Rise; TheraGun

LIST OF ABBREVIATIONS

AAS – Acute Ankle Sprain
AC – Area of contact
AP – Action Potential
AS – Area of support
BS – Base of support
CAI - Chronic ankle instability
CE – Closed eyes
CNS – Central Nervous System
COP – Center of pressure
CNP – CAI NO PRE
CNPO – CAI NO POST
COM – Center Of Mass
CYP – CAI YES PRE
CYPO – CAI YES POST
DOMS – Delayed Onset Muscle Soreness
FS - FootScan
FL_{DOM} – Flamingo Unilateral Stand on the dominant lower limb
FL_{NON} – Flamingo Unilateral Stand on the non-dominant lower limb
HYP – HEALTHY YES PRE
HYPO – HEALTHY YES POST
HNP – HEALTHY NO PRE
HNPO – HEALTHY NO POST
LAS – Lateral ankle sprain
m. – Musculus (eng. muscle)
MG - Massage Gun
MHC – myosin heavy chain
n. – Nervus (eng. nerve)
OE – Open eyes
PS – Postural Stability
PT - Percussive therapy
PTOA - Posttraumatic osteoarthritis
RMT – resting motor thresholds
TTW – Total travel way

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1 INTRODUCTION

Injuries to the ankles, ligaments, and surrounding muscles are numerous in the sports world. Their occurrence is frequent, and recovery can be a major limiting factor not only in terms of sports specialization but can also cause significant complications in everyday life. Fong et al. (2007) identified ankle injuries as the most common injury in 24 of 70 sports (34%). At the same time, several studies show that lateral ligament injuries of the ankle are the most common sports-related injuries. This is approximately 25%. Despite this fact, Bonnin (1950) was the first to mention that the frequency of ankle sprains is dependent on muscle activation and control. Labanca et al. (2021) demonstrated that people with chronically unstable ankles have delayed neuromuscular activation of the m. peroneus longus. Bowker et al. (2016) also observed changes in neural excitability at m. soleus in patients with chronic ankle instability (CAI). These changes can be observed on the H-reflex measured from EMG, which tends to be significantly reduced in people with CAI (McLeod, 2015). However, many more parameters can be observed in CAI patients. Nevertheless, this thesis mainly deals with the effect of percussive therapy, which according to many manufacturers can activate the treated muscles and thus improve their performance. Thus, we hypothesize that the use of PT could positively affect postural stability performance in CAI population, and that postural stability (both dynamic and static) and associated altered muscle activity in the calf area would be significantly improved.

Although massage guns (MG) like TheraGun^{TM} are a big commercial hit in the athletics world, there is still lack of scientifically based evidence that have been conducted to prove their effectiveness. In this master thesis, we would like to compare, confirm or refute the effectiveness of percussive therapy implemented with the TheraGun^{TM} on changes in muscle activation and postural stability in groups with different musculoskeletal conditions.

2 OVERVIEW OF THEORETICAL KNOWLEDGE

2.1 PERCUSSIVE THERAPY

Mechanical percussive massage therapy is increasingly used in the field of sports medicine and physiotherapy, but also becoming popular in the non-athletic world. The history of massage guns (MG) dates to 2007 when chiropractor Dr. Jason Werseland developed a deep tissue muscle MG after a serious motorcycle crash. Nowadays we use electric or battery-operated devices that have differently shaped prongs at the end of the head to affect different muscle areas at different frequencies, strengths, and amplitude values (**Figure 1**). "Each device touches and retracts away from the body 40 times per second (per second!), a precise calibration that distracts the brain away from pain while also delivering deep, effective treatment"(Therabody Internationale, 2023 – online 4). We are currently experiencing expert opinions that pre-exercise mechanical percussive massage may not effectively influence physiological processes leading to improved performance. Despite this, a couple of studies show improvements in the following parameters. Such as Konrad et al. (2020) found increased range of motion in dorsiflexion in recreational athletes, but this did not affect plantar flexor MVC after 5 minutes of mechanical intervention. Cochrane et al. (2010) confirmed significant changes in the rate of force development of the patellar tendon reflex, using the whole-body vibration therapy in the first five minutes after intervention. They also found increased values of mentioned parameters only in the acute phase of activation. This claim was then confirmed by Dallas et al. (2022). These changes can be explained by increased blood flow and intramuscular temperature (Lythgo et al., 2009; Cochrane et al., 2010). However, significant improvement was not found in the study by Szymczyk et al. (2022), who did not demonstrate significant changes in jump height following the use of PT. By summarizing the available studies, we can say with some caution that PT primarily affects range of motion and tendon-muscle reflex activity.

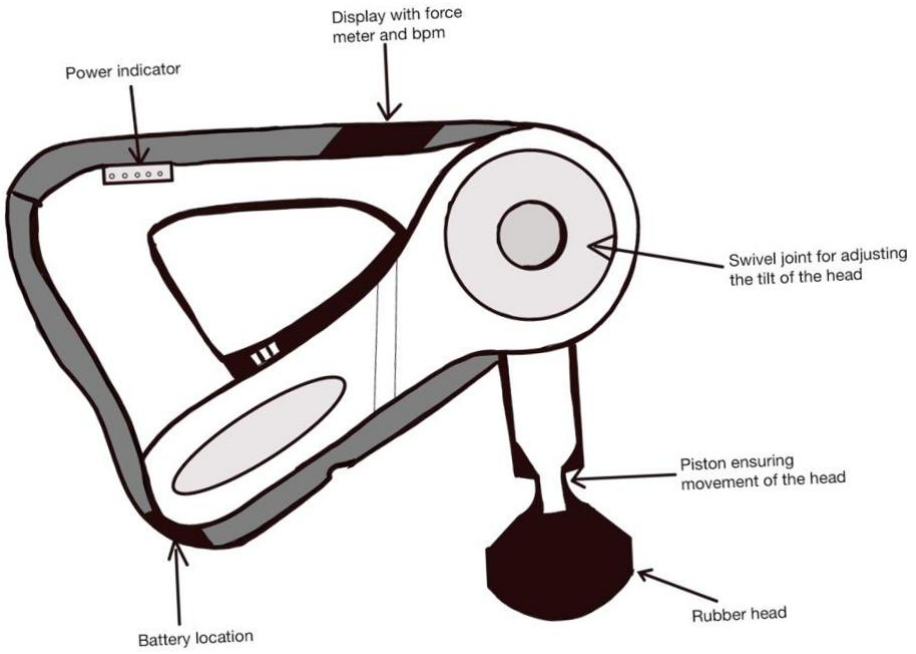


Figure 1. Massage gun we used for percussive massage therapy with the description (pic made by author).

2.2 POSTURAL STABILITY

"Postural stability is the ability to control the body position in space for movement and balance" (Woollacott et al., 2002).

Vařeka (2002) defines postural stability as the ability to hold the body upright and react to external and internal forces, if necessary, to avoid uncontrolled falls.

The posture itself then relies on the stabilizing ability of the lower limbs and spine. This involves the individual body segments and the constant analysis of their occurrence in space, which is the responsibility of the CNS (Le Ray et al., 2022). Stability, especially postural stability, then depends not only on external forces and physical parameters (the size of the support surface, gravitational forces, height, or weight) but above all on muscular activity, which can compensate for these external and internal factors to the necessary values.

Gryc (2014) divided the postural stability components into 3 segments:

1. sensory component
2. control component
3. executive component

2.2.1 The sensory component

The sensory component provides the organism with information about the external and internal environment. The individual receptors receiving this information can transmit stimuli via neural pathways to the different parts of the cerebral cortex. Sensory pathways are divided into exteroceptors, interceptors and proprioceptors.

Exteroreceptors – are a superset bringing information from the external environment and the ability to mediate its transmission to the nerve centers. There are 5 human senses - touch (tactile bodies in the skin), smell (regio olfactoria of the nasal mucosa, with action in the paleocortex), vision, hearing, and taste (taste buds of the tongue, with action in the thalamus - gyrus frontalis). The different groups of receptors can then be specified and divided according to the stimulus into mechanoreceptors (touch, balance, hearing), photoreceptors (vision), chemoreceptors (smell, taste), thermoreceptors (cold, heat) and nociceptors (pain).

Interceptors - are a superset for receptors capable of sensing distributed signals from the body's internal environment, such as chemoreceptors (at ventral medullary surface, lateral hypothalamus, locus coeruleus, ncl. facialis, superior olive, etc.).

Proprioceptors – refer to deep sensitivity. Specifically, they consist of mechanoreceptors in the muscular system, i.e., neurotendinous organs and muscle spindles. Proprioception itself is then the cornerstone for the coordination of movement, regulation of muscle tone, and changing the body segments in space.

Both information from the vestibular organ and proprioceptive sensors in muscles, tendons, joint capsules, and ligaments are used to continuously maintain and stabilize the initial position, providing information about the position of the head and individual body segments (Véle, 1995). The most important sense for keeping oneself posturally stable is an active vestibular system with vision (Hatzitaky et al., 2002; Rival et al., 2005). For our research, the cooperation of the vestibular apparatus, vision, and especially proprioception will be the most relevant.

Proprioception brings signals from kinesthetic and somatosensory analyzers such as muscle spindles, tendon bodies, and joint receptors. The muscle spindle responds to the change in muscle fiber length and the rate of this change. Golgi tendon cells are less sensitive and provide information about the magnitude of the contraction. Tactile and pressure analyzers are located in different layers of the skin especially in the plantar region of the feet (Bartunková, 2006). Therefore, proprioception is one of the most important components in dynamic work and functional stability. This is both in active athletes and in everyday activities (Lee et al., 2006).

2.2.2 The control component

The main controlling and integrating system of the organism is the nervous system. The main function is to process every neural signal and send them to the effectors. CNS is made up of the spinal cord and the medulla oblongata, the rhombencephalon such as the pons Varoli, the cerebellum, the mesencephalon, the basal ganglia, the limbic system, and the cerebral cortex.

The spinal cord consists of the grey and white matter of the spinal cord and its function consists mainly in its participation in motor activity, carried out based on spinal reflexes. The medulla oblongata contains nuclei involved in autonomic functions and houses motor centers that control muscle tone and postural reflexes. The mesencephalic nucleus is involved in the motor coordination of influences from the cerebral cortex and cerebellum. The mesencephalon itself has motor and sensory functions. The reticular formation is formed by a system of descending and ascending pathways and is thus significantly involved in the coordination of life-sustaining functions. The ascending activating portion of the reticular formation emanates from the truncus cerebri, and up through the thalamus into the neocortex.

Involved in wakefulness and memory storage. The descending inhibitory part of the reticular formation originates from the cerebral cortex and is subsequently activated from the basal ganglia and the cerebellar spinal cord. Intentional movements are thus inhibited. The descending facilitative part maintains upright posture and body positions, precisely because of the facilitation of the antigravity muscles. Both facilitative and inhibitory parts are involved in the excitability of gamma moto neurons (Seidl, Obenberger, 2004).

2.2.3 The executive component of lower limbs

Maintaining postural stability is a complex process involving the peripheral and central nervous systems and the musculoskeletal system as the executive component. The cooperation of the sensory, control, and executive components form the mechanisms that ensure postural stability at rest or in motion initiation/preservation.

The lower limbs transfer the gravitational load of the body through the hip, knee, and ankle to the foot. The postural function of the lower limbs is to provide firm contact with the ground, maintain and correct stability, and as a sensor system for postural changes.

The main mechanisms providing postural stability in standing are the tibial mechanism in the anteroposterior direction and the hip mechanism in the later-lateral direction (Winter, 1995). The postural system is still active. The input signal will always elicit a response in the whole system but differentiated differently programmatically. The postural system is activated differently by a sudden change in the environment, to which it is forced to respond immediately, and differently by the preparation and anticipation of movement, to which it responds deliberately (Véle, 1995).

2.2.4 Static and dynamic postural stability

Two different strategies, static and dynamic, are used in maintaining postural stability. The static strategy is represented by the balance responses by which the control system attempts to maintain an upright posture without changing the contact area. In unstable postures, if the stability of the stance is compromised when the projection of the center of mass (COM) of the body, also represented as a

center of pressure (COP), is displaced outside the support base, the control system adopts the so-called dynamic strategy to restore postural stability by repositioning the contact surface so that the projection of the center of gravity of the body is again inside the support base.

For static postural stability, the integration of visual and proprioceptive information is dominant, whereas dynamic postural stability is influenced by the ability to quickly form an individual motor response (Hatzitaki et al., 2002). The difference between the two types of balance control (postural stability) also stems from the motor response that is formed by the CNS. Different motor strategies are used to maintain static and dynamic balance and are influenced by motor learning through a life span (Hatzitaki et al., 2002). Static balance uses a closed-loop feedback system (Nashner, 1976), where proprioceptive information from all parts of the body is integrated and processed at a central level, thus contributing to the maintenance of a stable posture. Dynamic balance additionally requires the use of anticipation, involving a system called *feedforward control*, which predicts possible future misalignment and forms a motor response based on using proprioceptive and vestibular information (Schmidt, 1991; Hatzitaki et al., 2002).

As mentioned above, all components are integral to postural stability. The executive component is thus influenced in its function by information from the control component, which freely or reflexively receives stimuli from receptors in the sensory component. Freeman et al. (1965) (in Riemann, 2002) demonstrate impaired postural stability in people with CAI. They also suggest that this may be influenced by a deficit in neuromuscular transmission, specifically a deficit in afferent input derived from the mechanoreceptors of the ankle complex. Lentell et al., 1995 (in Riemann, 2002) demonstrate that people with CAI have deficits in proprioceptive sensation (kinesthesia and joint position sense). However, Tropp (1986) did not observe significant bilateral differences in football players. Patients with CAI did, however, demonstrate a higher COP excursion (Mettler et al., 2015). Thus, Riemann (2002) offers 2 possible interpretations - (1) patients with functionally unstable ankles may be predisposed to functional instability, as evidenced by poorer performance on the contralateral healthy limb; and (2) functional ankle instability affects the postural control system at a level that is high

enough to affect postural stability on both limbs. This may be the subject of further investigation; the purpose of this study was to determine if the use of PT would lead to improved static and dynamic postural stability.

2.2.5 Postural stability assessment methods

Postural stability measurement, also known as posturography, is the assessment of dynamic and static postural stability at a quantitative level in laboratory conditions. We are now able to use several posturography instruments. In most cases, this is a cheap and quick examination method that uses scanning platforms as the data source.

Unlike electronystagmography, dynamic posturography does not provide an exact localization of the source of the postural stability problem, so it is "just" part of a typical diagnosis to confirm or refute any changes.

Examples of instruments to measure and assess postural stability –

1. **Biodex system** – uses a system based on microprocessors that regulate the stability of the suspended force plate of circular shape. The force plate is tilted in a 20-degree angle and at a sampling frequency of 100Hz it expresses deviations from the basic stability of the test subject. The patient's test score is evaluated based on the off-center deflection. Thus, the lower the score, the better postural stability can be observed (Pickerill et al., 2011; Poonam Pravinkumar, 2019).
2. **NeuroCom Smart Balance Master -** measures postural stability using the Limits of Stability (LOS) function. This function is defined as points at which COG approaches the limits of base of the support and a correction is usually required to get the COM back to inside the base of support region (Ragnarsdottir, 1996). The device uses two force plates connected by a single joint at their center on the front and back. Each plate joint is connected to vertically oriented electronic devices, supplemented by a single horizontal sensor (Pickerill et al., 2011; Poonam Pravinkumar, 2019).
3. **FootScan –** a method that uses a dynamographic pressure platform to analyse the pressure between the foot and the pad. The FootScan strain plate was originally created as a running stride analyzer, and customized running

shoes were then created based on this data. Now the platforms are used to measure postural stability, plantar pressure, or foot splay in static and dynamic activities (Václavíková, 2016).

2.3 SKELETAL MUSCLE ACTIVITY

2.3.1 Skeletal muscle physiology

Muscle fiber activation

Action potential in skeletal muscles

Movement starts in the motor cortex, basal ganglia (specifically in ncl. subthalamicus, substantia nigra and ncl. penduculopontinus), which directs very specific signal into the spinal cord, followed by send of its outputs to the muscles. All of this wouldn't be possible without the proper information transmission made by action potentials. In this thesis we are considering 2 "types" of action potentials. Motor unit action potential (MUAP) and action potentials (AP). MUAPs ensuring the muscle contraction thanks to the cooperation with neuromuscular junction. On the other hand, the APs are the messengers of neural information about the movement.

Unlike the cells of plants or unicellular animals, nerve and muscle cells are capable of changing membrane voltage very rapidly (Hodgkin, 1952). This excitability is attributed to the closable ion channels that can control membrane permeability to individual ions (Williams, 1981). By making individual ions carry a positive or negative charge, we are thus able to change the voltage ratios across the membrane. The individual states are then referred to as resting membrane potential, hyperpolarization, and depolarization.

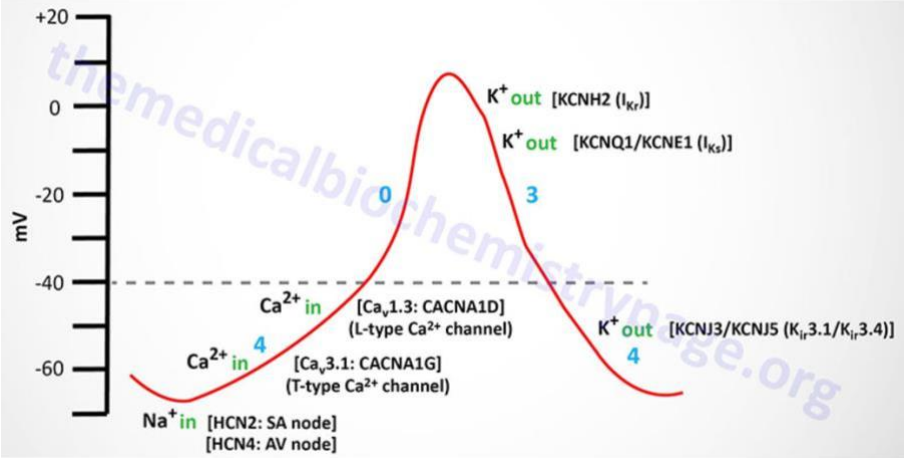


Figure 2. Action potential - If the depolarization exceeds a stated threshold, the cell begins to re-polarize to positive values where, due to ionic depletion by repolarization, we return to resting levels (ONLINE 1).

Typically, an action potential is generated at the axon hillock (Stevens, 1966) along with the necessary strong depolarization. At the resting state, the neuron has a high concentration of sodium (Na) and potassium (K), in the intracellular fluid relative to the extracellular fluid (**Figure 2**). This difference in concentration causes an electrostatic effect that influences movement of ions in and out of the neuron. The inside has a negative charge compared to the outside of the cell. This is because of the movement of K+ out of the cell. At the onset of the threshold depolarization of 15 mV, voltage channels open, leading to a constitutive transfer of Na+ into the cell. This changes the internal charge of the intracellular space. The rate of action is measured in units of milliseconds until the threshold of +(50-60) mV is reached, and the so-called "spike" is reached. This sharp rise in mV and sodium permeability correspond to the rising of the action potential (Bullock, 1977; Junge, 1981; Purves, 2008). In the very peak of spike is state called “absolute refractory period” (Stevens, 1966; Bullock et al., 1977; Purves, 2008). Subsequently, the polarity is reversed - the surface is electronegative compared to the interior. This condition is called transpolarization. Only then, when Na+ channels are closing, the opening of K+ channels reach a peak. Potassium flows along the direction of its concentration gradient. This results in the restoration of the original values. This leads to the repolarization phase.

Vesicles and neuronal terminal membrane proteins (e.g., synaptobrevin and synaptotagmin) are the primary factors influencing synaptic vesicle fusion and with

it the exocytosis of acetylcholine into the synaptic cleft. Acetylcholine is then bound to nicotinic receptors in the junctional folds. Thus, in the neuromuscular junction, the terminal potential is strong enough to propagate AP across the skeletal muscle membrane surface to provide muscle contraction. To prevent sustained contraction, acetylcholine is metabolized by acetylcholinesterase to choline and acetate (Jimsheleishvili et al., 2023; Ratliff et al., 2018; Omar et al., 2023).

2.3.2 Muscle fiber mechanics

Muscle fiber contractions

Any deformation, such as a change in position or shape, of physical material objects in space and time is defined as motion. Movement of living objects are a fundamental principle for the maintenance of life in living organisms.

For every movement, the basic 4 properties of muscle tissue are crucial - namely excitability, contractility, extensibility, and elasticity. For skeletal muscle, there are 2 basic functions - *kinetic* and *stabilisation/fixation*. During contraction, the muscle can shorten by 30-40% of its own length compared to its resting length (i.e., the length of the muscle which is not deformed by the external force). The speed of muscle contraction lasts on average 50 milliseconds depending on the type of muscle fiber (Lieber, 2010). The amount of stroke and the force with which the movement is performed depends on the internal structure of the muscle. Muscles with parallel spaced longitudinal fibers have a greater stroke length but less force than muscles with oblique bundles for the same shortening.

In a muscle with oblique fascicles, a greater number of short muscle fibers are involved in the same size belly. If a muscle with longitudinal bundle adjustment is shortened by one-third, it has a greater lift height but less force. If a muscle with oblique bundles is contracted by a third, it has a small stroke height, but a large force can be generated (Lieber, 2010).

With this, we recognize 3 types of contractions:

1. **Concentric contraction** – muscle activation providing tension that shortens the muscle. The shortening of the muscle provides the ability to generate sufficient force to lift objects.
2. **Eccentric contraction** – muscle stretches due to lack of muscle strength. The main purpose is to slow down the movement.
3. **Isometric contraction** – thanks to the type of this contraction we can ensure the immobility of the joint in front of which the force is directed. The force component generated by the muscle is exactly equal to the weight of the object being manipulated.

Muscle fiber types

The heterogeneity of the muscle fibers is differentiating all over the mammal species (Goldstein, 1971). Very own of muscle fibers can be seen in human skeletal muscle system, which is specific against the other mammals due to the changes of myosin heavy chain (MHC). Thus, in a very basic division, muscles can be divided as type 1 (slow-twitch) and type 2 (fast-twitch).

Based on MHC gene expression, we are now able to classify fast-twitch (2t) fibers into 3 basic subcategories - 2A, 2X, 2B. Hybrid MHC expression is then able to differentiate the aforementioned fiber types into categories 1/2A; 2A/2X; 2X/2B, the presence of which allows ATP molecules and muscle contraction rates to continuously range from the fastest to the slowest fibers.

Type 1 and 2A - their primary energy production is the use of oxidative metabolism (**Figure 3**). On the other hand, type 2X and 2B utilize glycolytic metabolism. However, it has been reported that determining muscle fiber type based on energy utilization alone is not a completely accurate predictor (Pette et al., 2000; Schiaffino et al., 2011; Talbot et al., 2016). Furthermore, their identification also involves distinct components of the sarcomeric contractile apparatus - for example, tropomyosin isoforms (Tajsharghi, 2008) or preferentially expressed microRNAs in a particular muscle type, thus modifying the regulatory mechanisms specific to a particular fiber type (Liu et al., 2013; Muroya, 2013; Talbot et al., 2016) and giving it unique properties.

The difference in muscle fibers allows them to represent different roles in different tasks. Type 1 with high oxidative volume is made for endurance exercise (Plotkin et al., 2021). Type 2b fibers have relatively low oxidative capacity due to the capillary density. Its main function is in resistance exercise. Type 2a are known for its hybrid character, that allows typically good power generation even with good endurance.

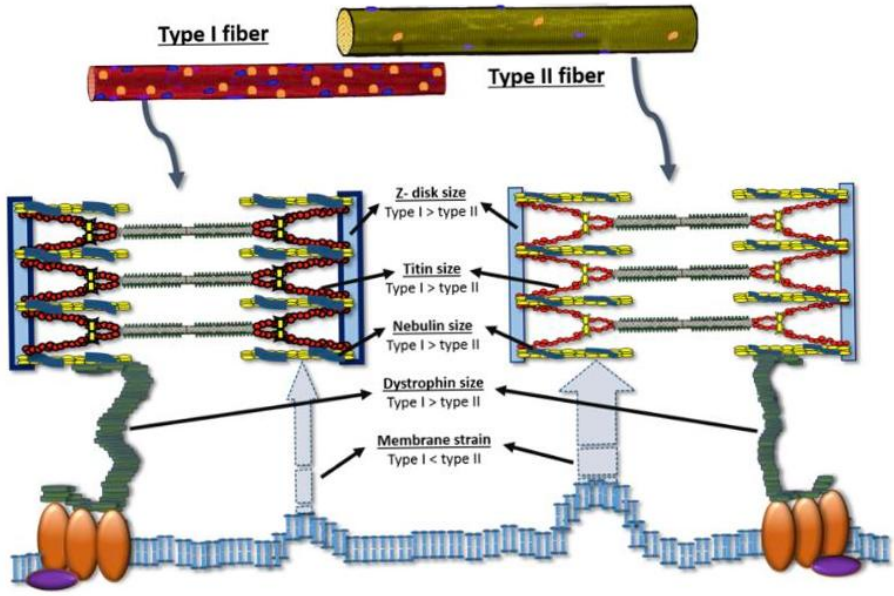


Figure 3. Ultrastructural differences between type 1 and type 2 fibers related to exercise-induced damage. Due to smaller Z-disk, titin, nebulin and dystrophin, the type 2 fibers are more suspectible to injury (Qaisar et al., 2016)

Motor unit

Motor unit (MU) is the basis of the motor system. It is a set of muscle fibers innervated by a single motoneuron. The MU is characterized as the smallest component that can be independently activated. The axon of the motoneuron branches after entering the muscle, its terminal fiber innervates one muscle fiber at a time. Motor units thus represent the peripheral motoneuron unit.

CNS is responsible for the recruitment of motor neurons by the law of Henneman's size principle (Gordon et al., 2004). MU are recruited from the smallest to the largest based on the load. CNS is controlling the MUs by 2 ways – *spatial* recruitment and *temporal* recruitment.

Spatial recruitment is caused by the higher amount of motor units, which allow the muscle to generate great force (Lee et al., 2013). Temporal recruitment, also known as rate coding, is neuronal firing kind of communication that is increased when then stimulus intensify. In this case we are able to observe not only typical action potentials, but even graded potentials which do not operate only on the basis of the "all-or-nothing" law, but also incorporate electrotonic potentials, subthreshold oscillations of the membrane potential, or synaptic potentials etc. They typically arise on the postsynaptic dendrite after firing of the presynaptic neuron.

2.3.3 Muscle activity assessment methods

Electromyography

Electromyography (EMG) is an electrophysiological examination method used mainly in neurology. It is a specific sensing of electrical activity and its propagation in the neuromuscular system.

The main segment examined is the examination of electrical activity not only at rest but also during volitional activation. All electrical responses of a given muscle are sensed by electrodes on the muscle under investigation.

The recording itself is a defined difference between two sites. Specifically, one active electrode, placed on the part of the muscle that is active, and a second, reference electrode, which is placed on the less active part of the muscle. The surface electrodes themselves sense information from a larger area and we are therefore unable to measure the action potential of individual motor units with them. During zero voltage we observe the basal line i.e., the resting state of the muscle.

The electrode spacing should be as small as possible to reduce the possibility of cross talk (Krobot & Kolářová, 2011), i.e., unwanted influence of the EMG signal by the electrical activity of the muscle fibers around the sensed muscle. De Luca (1997) strictly prefers a distance of 1 cm. In the case of sensing small muscles, the inter-muscle distance should not exceed ¼ of the muscle fiber length.

When the signal is sensed from two electrodes (reference and active), electromyography uses differential amplifiers that amplify only the difference of signals from these two electrodes. This suppresses noise offsets (co-phase signals)

that have identical amplitude for both electrodes. The suppression of artifacts while preserving the sensed signal is called the rejection factor. (Keller, 1999; Deuschel, 1999) Most modern amplifiers are designed for skin impedances in the range of 5-50 kOhm (Konrad, 2005). Commonly, skin impedance is in the higher numbers, so it is necessary to clean it. Alcohol is used for degreasing and an abrasive paste can be used to remove dead cells. It is advisable to remove hair from the area under the electrode. Sometimes a conductive gel or paste is used between the electrode and the skin to significantly facilitate signal transmission from the muscle (Criswell, Cram, 2011).

"A surface EMG signal represents the linear transformation of motor neuron discharge times by the compound action potentials of the innervated muscle fibers and is often used as a source of information about neural activation of muscle." (Farina et al.,2014).

In sports science, sEMGs are used extensively primarily because of the relative ease of obtaining recordings, which are relatively reliable in reflecting both the neural apparatus directed to the muscle under investigation and the muscle force.

Motor units action potentials (MUAPs) are not fully visible in sEMG. Since sEMG is less selective (Merletti et al., 2009), we observe mostly clusters of APs from bulk populations of MUs in the record. In contrast, in low contractions we can observe individual MUAPs with sEMG (see **Figure 4**). In summary, sEMGs provide general information on the activity of MUs and, in rare cases, information on individual MUs (Cavalcanti Garcia, Vieira, 2011).

Surface electrodes are usually made of silver or other well conducting and corrosion resistant conductor. The electrodes are then bonded to the skin using leucoplasty or a similar method. The skin must be dry and non-greasy for proper signal transmission. The maximum occurrence of the signal is in the frequency range 50-150 Hz (De Luca, 1993). Unlike intramuscular EMG, the surface electrode records from muscle fibers at a maximum depth of 20mm (Keller, 1999).

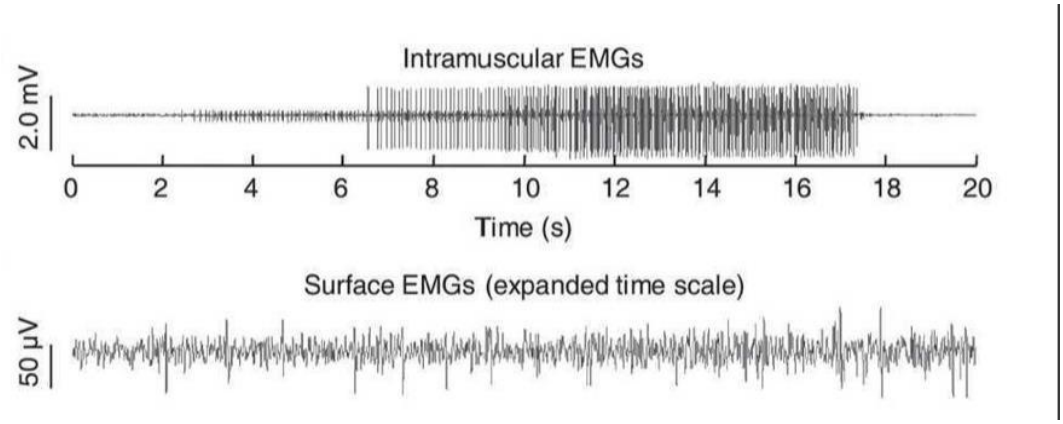


Figure 4. Difference in the display of single action potentials using surface and intramuscular EMG. (Modified from Cavalcanti et al., 2011)

Based on the available research and knowledge, we are asking, if there is a significant difference in postural stability performance and muscle activity during movement initiation before PT application? Are we able to use percussive therapy and its mechanism to affect postural stability in people with chronically unstable ankles? Does muscle activity of calve muscles sensed by surface EMG (sEMG) during stable postures and dynamic balance change after using PT? Is there any significant difference between muscle activity and postural stability between the CAI and healthy people after PT use? Because of this, the aim of the research was to examine the differences in postural stability and muscle activity during movement initiation between healthy and CAI subject, and to examine the effect of PT on muscle EMG activity of lower limb in relation to postural stability and muscle activation performance before and after PT application.

2.4 CHRONIC ANKLE INSTABILITY

2.4.1 Ankle joint complex

The whole ankle complex is a big problem from an anatomical and functional, biomechanical point of view. The movements in the ankle take place, among other things, in 3 joints (talocrural, subtalar, tarsal). The muscles around these joints thus must work in multiple planes, which also change during the stride. Although the primary anatomical connections of the ankle are the interosseous contact surfaces and mainly the ligamentous components, it is the muscular (and neural) component that provides the movement in the ankle. The movements in the ankle can be divided into several categories, including rotation, however, the main movements are divided into 2 - plantar flexion and dorsiflexion. The main components of the muscular component are the m. gastrocnemius and m. soleus. The function of this muscle group is plantar flexion of the leg, we can call it an agonist of this movement. Together with the musculus peroneus longus et brevis, the musculus tibialis anterior et posterior and the flexors and extensors of the toes and big toe, it forms the superficial stabilizers of the talocrural joint. Kapandji (2011) states that these are also very important stabilizers of the knee joint and at the same time antagonist to the m. quadriceps femoris and m. tibialis anterior.

2.4.2 Bone structures in the ankle joint

Talocrural joint

The joint stability of the talocrural joint (TalCruJ) itself is biomechanically stable. The upper part of the TalCruJ includes the tibia (medially) and fibula (laterally) and inferiorly the talus (**Figure 5**). The tibia and fibula form the tibial fossa, an inverted U-shaped structure that forms the proximal segment of the TalCruJ. Those articular surfaces on the inner surfaces of the medial and lateral malleolus are convex. On the other side, the inferior surface of the tibia is concave (McKeon et al., 2019). Below the fossa is the tibia, the body of which is wedge-shaped, the neck and the globular head extending forward at an approximately 90-degree angle to the tibia. The body of the calcaneus is wider anteriorly and has 1 convex facet. The two concave facets on the outer walls extend approximately halfway down the sides of the body of the talus. These 3 facets articulate with the

facets on the tibia and fibula. The greater surface area of the talus is used more for articulation with the tibia than with the fibula. However, the fibula is extending more inferiorly on the lateral side of the TalCruJ than the medial malleolus, allowing for increased contact surface area. The reciprocating concave-convex features facilitate the motion of the TalCruJ. Altogether, these 3 structures provide considerable bony commonality that gives stability to the TalCruJ. Last but not least, an articular surface is covering the head of the talus (McKeon et al., 2019).

Subtalar joint

There are three separate joints between the talus and the calcaneus. The lower surface of the talus has 3 facets (anterior, middle, and posterior facets of the calcaneus), while the calcaneus has 3 surfaces (anterior, middle, and posterior facets of the talus). The posterior and medial facets of the talus are on the body and the anterior facet is on the underside of the talar head. The largest articulation, which forms the posterior facets, is concave in shape on the side of the talus and convex on the side of the calcaneus. The remaining 2 facets are flatter; there is an expressive glide between these surfaces rather than rotation per se. There is a gap between the articulated medial and posterior facets that extends from the medial to the lateral side of the subtalar joint (tarsal tunnel). When the space widens laterally, it becomes the sinus tarsi. A fourth subtalar joint exists between the talus and navicular bones. It plays an important role in physiological subtalar movement. The subtalar joint is divided into two compartments. The posterior compartment, including the talocalcaneal joints on the posterior facets, is sometimes considered the anatomical or true subtalar joint. The anterior compartment also includes the junction between the medial and anterior facets of the talocalcaneal joint, as well as the articulation of the talus with the humerus (talocalcaneonavicular joint). Together, the anterior and posterior compartments are considered to be functional subtalar joint because the movements that take place between them cannot be segmentally separated during function (McKeon et al., 2019).

Tarsal joint

The tarsal joint (also known as Chopart's joint) is placed between the hindfoot and midfoot. It's typically divided into the 2 forms of synovial joints (talonavicular and calcaneocuboid joint (Juneja et al., 2023). The accompanying

movement pattern facilitates different functions depending on the position of the foot. The distinct movement pattern of the transverse tarsal joint facilitates different functions depending on the position of the foot. Under load, the metatarsal and cuboid become fixed and immobile, allowing the metatarsal and calcaneus to move relative to them. By these movements, the transverse tarsal joint facilitates inversion and eversion of the foot, which requires synchronous involvement of the subtalar joint. During these movements, the transverse tarsal joint is reinforced by several soft tissue structures (Rad, 2022).

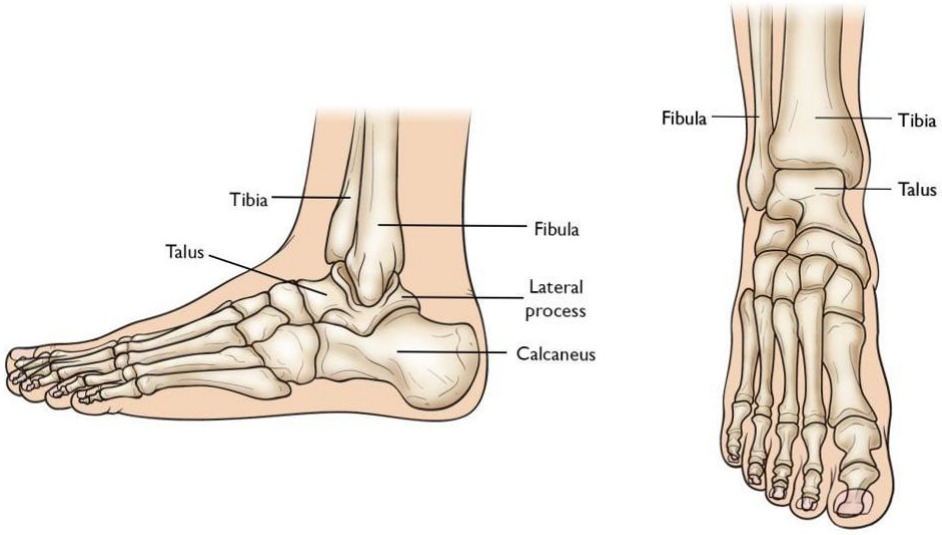


Figure 5. Lateral and anterior view of the ankle, bone structures described (ONLINE 2)

2.4.3 Muscle structures of the ankle joint

Musculus gastrocnemius medialis et lateralis

M. gastrocnemius medialis et lateralis belongs to the superficial layer of the whole muscle. Both muscles start at the femur, on the upper condyles. The two heads then join to form the Achilles tendon, which then attaches to the calcaneus. M. gastrocnemius medialis et lateralis additionally assists in the flexion of the knee. As it is a postural muscle - it provides flexion-extension synergy in the patella, and rotational stability of the knee and actively participates in knee flexion. In terms of kinesiology, m. gastrocnemius vastus lateralis alone is not a significant influencing element in the context of ankle stabilization. However, as a biarticular muscle, it contributes to both knee and ankle function and is thus fundamental to both gait and

postural function (Bordoni, 2022). The use of PT specifically may not affect PS just for ankle stabilization, but due to chaining we can assume an effect on knee-ankle cooperation and thus a significant effect on PS or dynamic performance during movement initiation.

2.4.4 The mechanism of the nervous components of the ankle

When the muscle fiber is stretched, afferentation of the muscle spindle induces monosynaptic activation of alpha moto-neurons of the homonymous muscle (Ellaway et al., 2015). Excitability requires sufficient relaxation of the antagonistic muscle to sufficiently optimize function, as mentioned by Sherrington (1913). This seemingly simple model of muscle interplay and coordination cannot always be explained by functional needs. It has been generally accepted consensus that alpha-motor neurons are reciprocally inhibited during voluntary movement by Ia-afferent fibers (Knikou 2008). The reciprocal inhibitory pathway has been described in detail through intramuscular recordings in humans (Kudina 1980). Reciprocal Ia afferent fibers inhibit antagonistic motor neurons via at least one inhibitory interneuron (Crone et al. 1987). Reciprocal inhibitory neurons contribute to postural and motor control through task-dependent amplitude modulation. The functional role of this reciprocal inhibitory pathway in various motor tasks, particularly bipedal locomotion (Petersen et al. 1999) and posture (Kasai et al. 1998), has been addressed by the professional community. However, these particular studies focused on the amplitude modulation of reciprocal inhibition during a specific movement.

2.4.5 Biomechanics of the ankle joint

The primary osteokinematics in the ankle joint are dorsal flexion and plantar flexion. It occurs roughly in the cardinal sagittal plane. In the anatomical position with the foot positioned at 90 degrees to the tibia, the talocrural joint usually has a higher range in plantar flexion than in dorsiflexion. During gait, the talocrural joint goes through two kinematic phases, namely alternating dorsal flexion and plantar flexion. (Perry et al., 2010)

The first phase occurs during the heel rocker and allows for force absorption at the beginning of the stride phase (Brockett et al., 2010). This is a deceleration that helps maintain a constant gait speed and allows for foot placement in preparation for weight transfer. The second plantar-flex phase occurs during the forefoot lunge (Brockett et al., 2010), and specifically this movement moves the body toward the front during the last phase. During this phase, the calcaneus, forefoot and toes are lifted off the ground. During the downtime phase between the two cycles, plantar flexion causes the ankle to rock (Perry et al., 2010). This locks the talocrural joint into a „closed-pack position "(Smith et al., 1988) and the foot becomes a more fixed point for efficient energy transfer.

On the articular surfaces, the talocrural joint is in the "closed-packed" position during dorsiflexion (Smith et al., 1988). The shape of the top of the talus body maximizes contact between the talus dome and the fossa. (Loudon et al., 1996) The talus compressively over dimensions the ligamentous structures of the tibia and fibula. This increases the pressure on each structure during dorsal flexion. In plantar flexion, the posterior part of the talus is in greater plantar contact with the fossa, reducing the bony stability of the talocrural joint (the "open-packed position") and placing the inferior tibiofibular ligaments in less tension. At this stage, there is an increased susceptibility to ligamentous components to stabilize the talocrural joint.

2.4.6 Lateral ankle sprain mechanism

The lateral ankle sprain (LAS) mechanism can be described as contact, indirect contact, and non-contact. The direct-contact mechanism involves contact to the inside of the leg immediately before or during impact, whereupon the leg is forcefully twisted into inversion (Olsen et al., 2004). Indirect contact involves contact with an obstacle or foreign weight that is forced to the ground due to the added weight (Fong et al., 2009). This type of LAS occurs predominantly in foot strikes by another person in contact sports and team sports. Non-contact LAS is caused only by the impact of the foot with no external forces to influence the impact (Hertel et al., 2002). Most LAS is characterized by talocrural plantar flexion, subtalar inversion, along with external rotation of the medial side of the foot.

In the US, approximately 2 million acute ankle sprains (AAS) occur annually (Waterman et al., 2010). Certain meta-analysis (Doherty et al., 2014) of 181 epidemiology studies of ankle sprains shows the data among various populations, which says, that overall, the incidence of AAS was higher in female population against the male population. Specifically, 13,6 vs. 6,9/1000 exposures (Doherty et al., 2014). Unfortunately, the data presented cannot be taken as complete, precisely because the above data come from emergency department and as we know from experience, not everyone with an ankle sprain visit the hospital. In this type of injury there is a very high risk of reopening an already healed injury. For example, according to Attenborough et al. (2014), volleyball players face recurrence of AAS in 46 % of cases, in American football we witness 43 %, basketball 28 % and 19 % in soccer.

Repeated injuries in the ankle area and very frequent and AAS lead patients to a chronic phase of unstable ankle, characterized by laxity and biomechanical instability that disables motor activity (Gribble et al., 2016). Gribble et al. (2016) also point to the fact that up to 70% of AAS convert to CAI within a short period of time after the injury in question. A cohort study presents a prevalence of CAI of 40% within the first year after AAS.

At the same time, patients with CAI also find this chronic type of injury very limiting during the "inactive" phase. Docherti et al. (2008) state that patients with functional ankle instability eviscerate the inability to exert the force of a running eversion maximal muscle contraction by 30% or less than patients who do not suffer from CAI.

Other factors that primarily contribute to CAI are bone deformities, and predominantly proprioceptive deficits and muscular weakness. Dynamic muscular stability in the ankle is biomechanically provided by muscular cocontractions, more specifically eccentric control, which leads to minimization of forces between the ground and the ankle complex (Dvir, 1995; Kaminski et al., 2002). Those parameters were described by Kaminski and Hartsell (2002).

- **Agonist-antagonist ratio** - Muscle balance around the ankles (LAS vs. HEALTHY leg) has long been taken as the gold standard of injury prevention (Perin, 1993 in Kaminski et al., 2002). Unfortunately, the

drawback is that the absolute measured values may still be lower after various interventions, making it difficult to predict the development of LAS or CAI (Kaminski et al., 2002).

- **Reciprocal muscle-group ratio** – a more traditional expression of muscle action mode ratios is EVCON/ INVECC ($CON_{evertor}/ECC_{invertor}$), which we consider to be a parameter indicating inverted strength or its deficit in people with CAI (Ryan, 1994; Wilkerson et al.,1997; Perrin 1993 in Kaminski et al., 2002). We also use the inverse EV_{ecc}/INV_{con} ($ECC_{evertor}/CON_{invertor}$) ratio (Kaminski et al., 2001; Buckley et al., 2001 in Kaminski et al., 2002), which describes the eccentric response of the peroneal muscles as the primary stabilizers of the ankle and a "retarder" of inversion in the open kinematic chain.

A disadvantage of CAI is in the progression of time of progradation into a pathological condition referred to as post-traumatic osteoarthritis (PTOA). This is an irreversible disease caused by, among other things, repeated AAS that gradually progresses to CAI. Gribbel et al. (2016) determine that AAS contributed to up to 22% of osteoarthritis affecting, among others, the ankles, and up to 80% of cases involve PTOA. The remaining cases are due to osteochondral pathological changes and of course fractures in the ankle region (Valderrabano et al., 2006).

2.4.7 Neurology in CAI topic

Corticomotor excitability in CAI

Pietrosimone et al. (2012) were the first to examine corticomotor excitability in subjects with CAI. Using transcranial magnetic stimulation, they determined that the CAI group had higher resting motor thresholds (RMT) values than the control group. This was in both lower limbs ($F_{(1,18)}=4.92$, $p=0.04$, $1-\beta=0.56$). Furthermore, such a correlation was found between FADI (functional ankle disability index) and RMT of m. fibularis longus ($r=0.4$, $r2=0.16$, $p=0.04$).

These values (increased RMTs) represent the fact that a higher amount of exogenous magnetic stimuli is required to excite cortical neurons leading to muscles in the periphery. Hiller et al. (38) (in Pietrosimone et al., 2012) demonstrated that neuromuscular responses, muscle strength and muscle response were not

significantly different in people with and without CAI. However, more complex tasks such as postural stability or gait are deficit in CAI subjects. Pietrosimone et al. (2012) thus suggest that more complicated tasks may be affected by changes in RMT.

3 OBJECTIVES, HYPOTHESES AND TASKS

3.1 Scientific question

Is there any significant difference in postural stability performance and muscle activation in the calf area in population with and without CAI history before and after 30s percussive therapy application?

3.2 Objectives of the research

The primary aim of this research was to evaluate and examine the differences in postural stability and muscle activation during static and dynamic movement performance in subjects with and without chronic ankle instability. Secondary, to examine the effect of percussive therapy treatment in the calf area on selected parameters of postural stability and muscle activation in people with and without chronic ankle instability.

3.3 Hypotheses of the research

H0: There is no significant difference ($p>0.05$) between selected parameters in postural stability and muscle activity during selected motor tests between HEALTHY and CAI subjects before and after percussive therapy application.

H1: CAI subjects show significantly different ($p<0.05$) results in selected motor tests when compared to HEALTHY subjects before percussive therapy application.

H2: Percussive therapy in the calf area has significant effect ($p<0.05$) on postural stability performance in CAI and HEALTHY subjects when compared to controls (without percussive therapy).

H3: Percussive therapy in the calf area has significant effect ($p<0.05$) on muscle activation in CAI and HEALTHY subjects when compared to controls (without percussive therapy).

3.4 Tasks of the research

1. Based on a literature search, gather available knowledge related to the issue at hand by the words chosen in the title and the words in the keywords.

2. Prepare an application to the Ethics Committee

3. To provide probands according to predefined criteria in both groups (patients with chronically unstable ankles, healthy patients).

4. Randomly assigning participants from both groups to the PT group and the control group.

5. To choose the telling tests to static and dynamic postural stability.

6. Select the muscle to which the surface electromyography sensor will be attached.

7. Determine the duration of massage for the PT group and the duration of rest for the control group.

8. Assess pre/post test results, differences between PT/CON and CAI/HEALTHY groups.

9. Based on the results, formulate conclusions of the research and recommendations for practice and further research.

4 METHODS

4.1 Participants

Total of 42 subjects in mean age of 23.5 ± 2.5 years participated in this research. From the original of 44 subjects, we had to discard 2 subjects (not finishing the measurement and extremely outlier data). The group was divided into 2 specific subcategories as follows – 21 patients with diagnosed CAI (CAI group; respectively) and the 21 of control group patients (HEALTHY group; respectively), including people who have never injured ankles, nor the ligaments and muscles group surrounding the ankle complex. The information and categorization based on the injury history to specific groups was performed by verbal questioning. The criteria for the CAI group were having had at least two ankle luxation or ankle distortions in the last 2 years as reported by a physician. The HEALTHY group was without this diagnosis. All the individuals involved in the testing underwent a medical examination by a sports physician at least once in a period of one year before testing. At the same time, the project did not include people with paraplegia, women in advanced stages of pregnancy, people who had feverish or acute inflammatory diseases within 7 days before the measurement. In addition, probands with current or healed rupture of m. gastrocnemius, m. soleus, tendo calcaneus, and probands who have purulent, fungal diseases, burns, scalds, varices, or any neurological diseases are not eligible to participate in the study. Subjects of both genders in both groups were then randomly divided (balanced ratio between male and female participants was kept) into 2 subgroups based on applied PT or not as follows: CAI YES (n=10), CAI NO (n=11), HEALTHY YES (n=10), HEALTHY NO (n=11). Study population characteristics of anthropometric parameters are shown in **Table 1** to **Table 5**. The probands were informed about the research process, which they also confirmed by signing an informed consent form according to Declaration of Helsinki. The master thesis research was approved by the ethical committee of Faculty of Physical Education and Sport, Charles University.

Table 1. Study population characteristics of anthropometric parameters.

n=42	AGE (years)	BODY HEIGHT (cm)	BODY WEIGHT (kg)
Mean	23.7	175.66	70.58
Standard deviation	1.29	10.1	12.26
MIN.	22	159	50
MAX.	26	193	100

Table 2. Overview of anthropometric parameters of the CAI YES group

n=10	AGE (years)	BODY HEIGHT (cm)	BODY WEIGHT (kg)
Mean	23.40	177.91	73.00
Standard deviation	1.20	11.47	9.92
MIN.	21.00	160.00	60.00
MAX.	26.00	191.00	84.00

Table 3. Overview of anthropometric parameters of the CAI NO group

n=11	AGE (years)	BODY HEIGHT (cm)	BODY WEIGHT (kg)
Mean	24.09	174.36	68.73
Standard deviation	1.56	8.43	10.78
MIN.	21.00	160.00	50.00
MAX.	26.00	187.00	85.00

Table 4. Overview of anthropometric parameters of the HEALTHY YES group

n=10	AGE (years)	BODY HEIGHT (cm)	BODY WEIGHT (kg)
Mean	23.80	176.40	71.70
Standard deviation	1.54	9.16	12.17
MIN.	21.00	161.00	53.00
MAX.	26.00	193.00	90.00

Table 5. Overview of anthropometric parameters of the HEALTHY NO group

n=11	AGE (years)	BODY HEIGHT (cm)	BODY WEIGHT (kg)
Mean	23.82	176.18	71.00
Standard deviation	1.27	10.64	15.14
MIN.	21.00	159.00	55.00
MAX.	26.00	192.00	100.00

4.2 Organization of measurement

Upon arrival, the proband was informed of the circumstances surrounding the measurement, read and signed the informed consent. Prior to the actual measurement, the principal investigator was trained and instructed by an experienced member of the Sport Research Centre of Faculty of Physical Education and Sport, Charles University. Also, the supervisor and physiotherapist were always present during data collection. After lying down on the gurney (see Figure 3a), basic parameters (age, laterality, height, weight) about the proband were entered into the system. Subsequently, the contact point on the m. gastrocnemius vastus lateralis was determined at the level of the highest palpably detectable point at the level of the 2/3 distal to the mentioned muscle. The muscle belly center point was palpated and visually controlled during sub-maximal voluntary contraction during plantar flexion in prone body position. Prior to the actual measurement, the site of sensor adhesion was treated with an alcohol wipe to disinfect the site. In men, in some cases it was necessary to shave the site of sensor adhesion with a disposable razor and only then disinfect it.

4.3 Procedures

4.3.1 Postural stability assessment

Data collection of Total Travelled Way (TTW) of Centre of Pressure (COP) during static postural stability tests was performed by pressure platform FootScan (RS Scan International, Belgium). Pressure sensors located in the platform sense load at frequencies up to 500 Hz. In particular, the parameter of Total Travelled Way of COP in mm (TTW) was evaluated and analyzed the postural stability tests consisted of two bilateral and one unilateral test.

First bilateral test was Close Stand with Open Eyes (**Figure 8**) (OE) in duration of 30 s. Subject was asked to stand on pressure platform as close as possible without touching the feet, ankles, or knees between dominant, and nondominant lower limb. Subject was asked to relax, free both arms besides the body and to stand as stable as possible in duration 30 s, while maximally concentrating on the sticker black point, centered, and located 1,5 m in front wall in the height of the eye level (individually set up). Second test was Close Stand with

Closed Eyes in duration of 30 s. Besides the same body and posture position, the subject was asked to close both eyes during 30 s stand performance. Third test was unilateral stand on one lower limb, also called Flamingo test (**Figure 9**) in duration of 30 s. Subject was asked to gently bend non-supportive lower limb into the air, approximately to 45° knee flexion. Eyes was open during this test. This test was performed for dominant (FL_{DOM}) and nondominant (FL_{NON}) lower limb separately. Dominance of the lower limb was examined and marked by verbal questioning of lateral preference of lower limb. During flamingo tests, subjects were able to choose which lower limb will be tested first. This was followed by 4 trials of Heel Rise test, which the FS recorded for 6s each. Subject was in close stand (arms free and relaxed beside the body) and by the tester command performed controlled heel rise to maximal available and comfortable height in tempo of 2 s concentric phase, 1 second stay in transfer position, and 2 s eccentric phase (**Figure 10**). Results of TTW in mm during each test were evaluated by FootScan software and assigned to individual subjects' results sheet in MS Excel (Microsoft, USA).

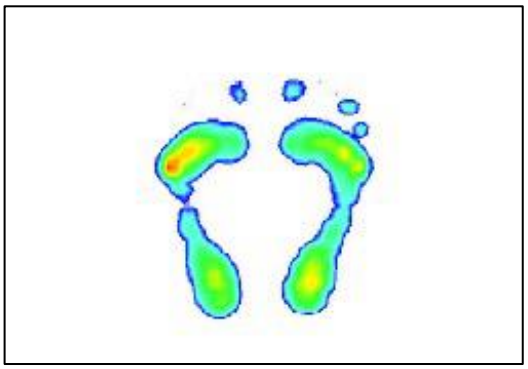


Figure 6. Screen visualization of pressure platform FootScan (RS Scan International, Belgium) during Close Stand performance.

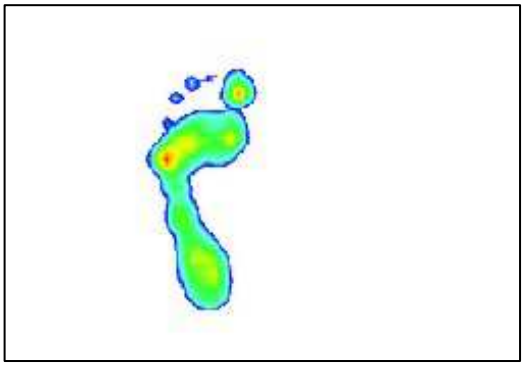


Figure 7. Screen visualization of pressure platform FootScan (RS Scan International, Belgium) during Flamingo Stand performance on one lower limb.

A) **B)**

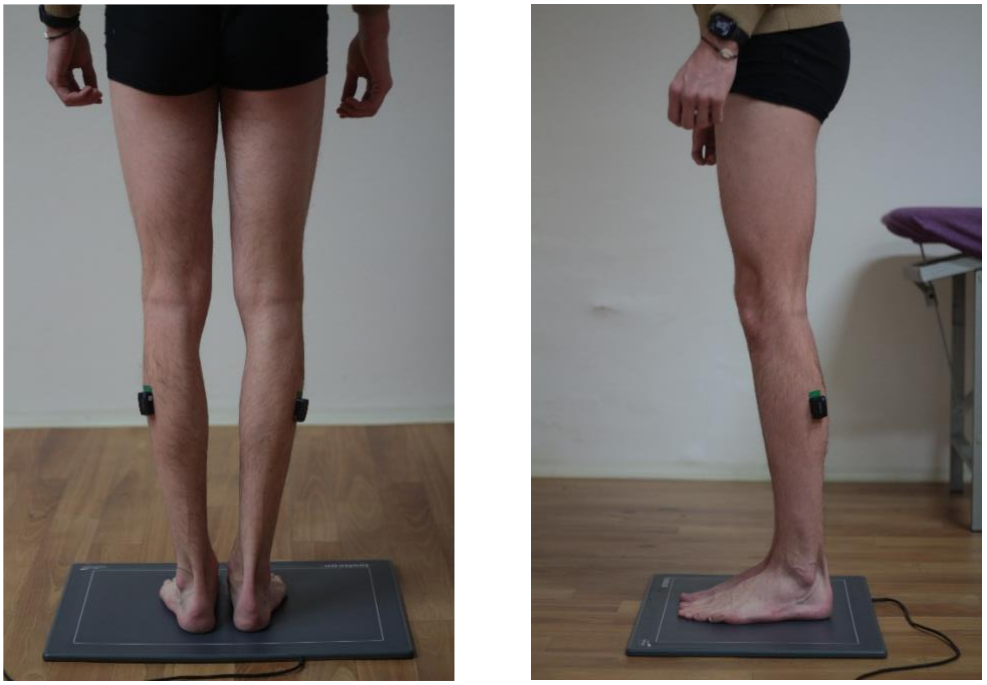


Figure 8. Close stand during postural stability tests. A) back view; B) side view

A) **B)**

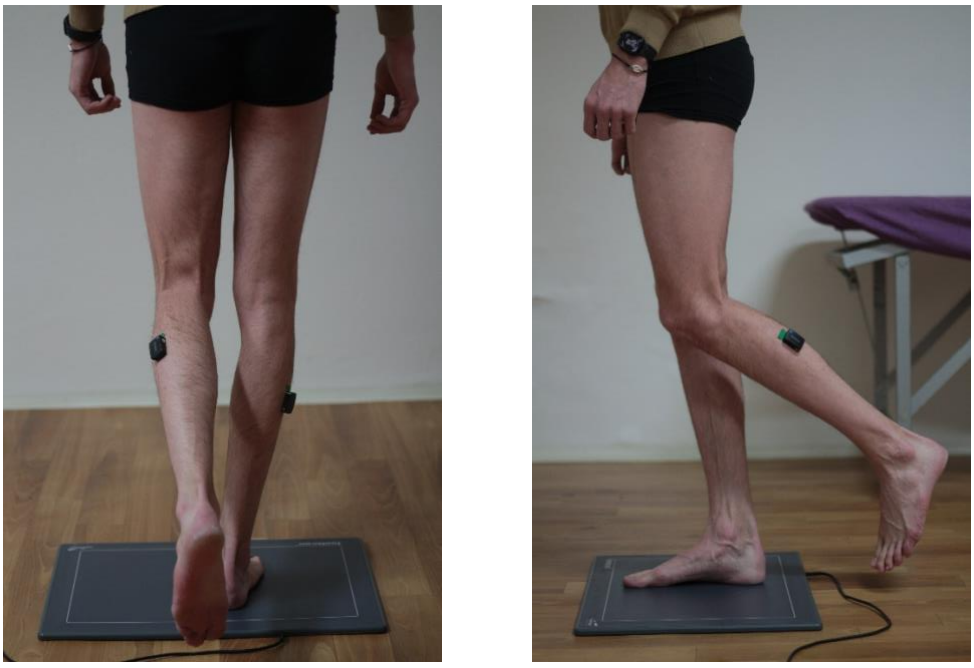


Figure 9. Flamingo stand during postural stability tests. A) back view; B) side view

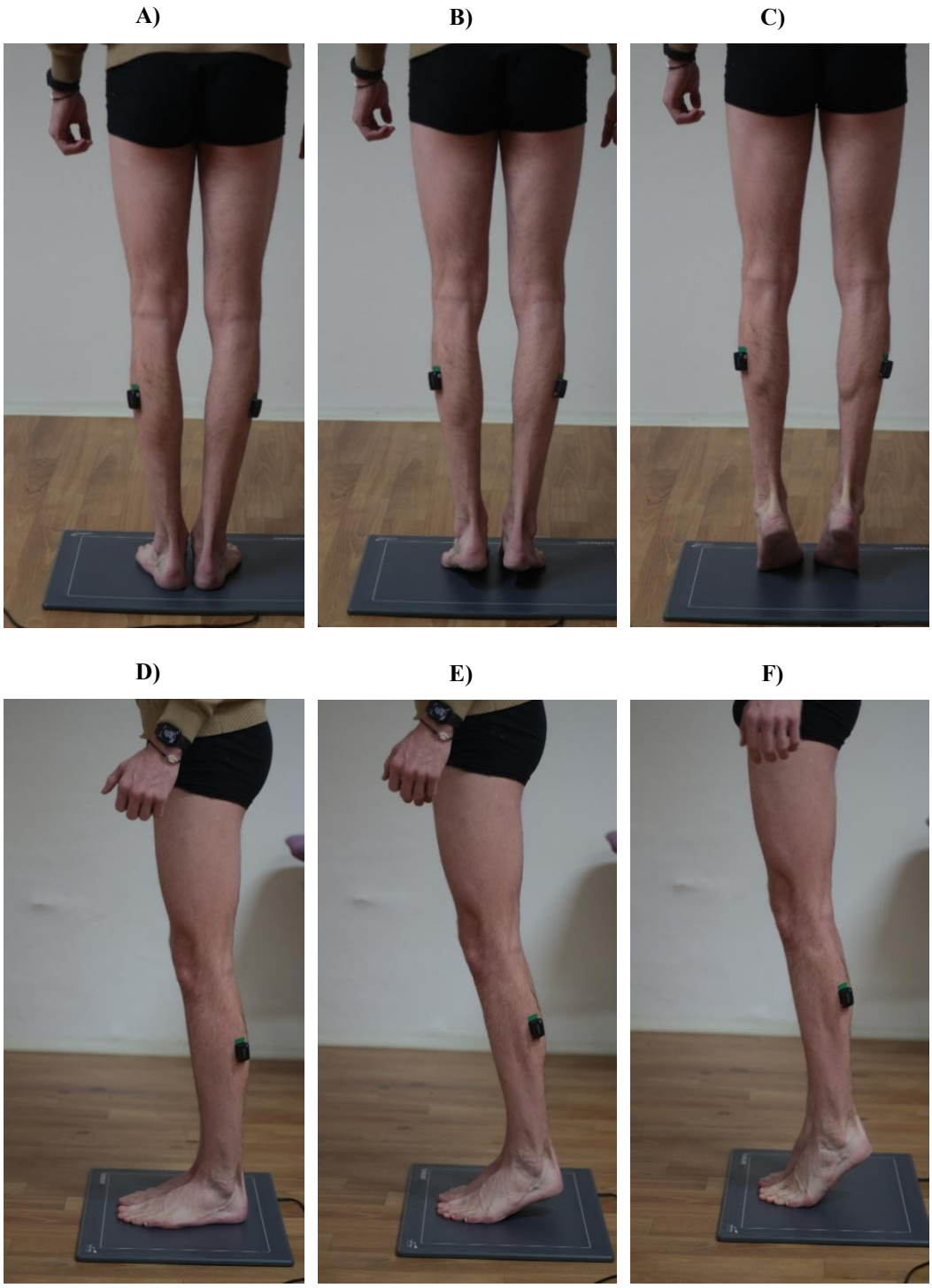


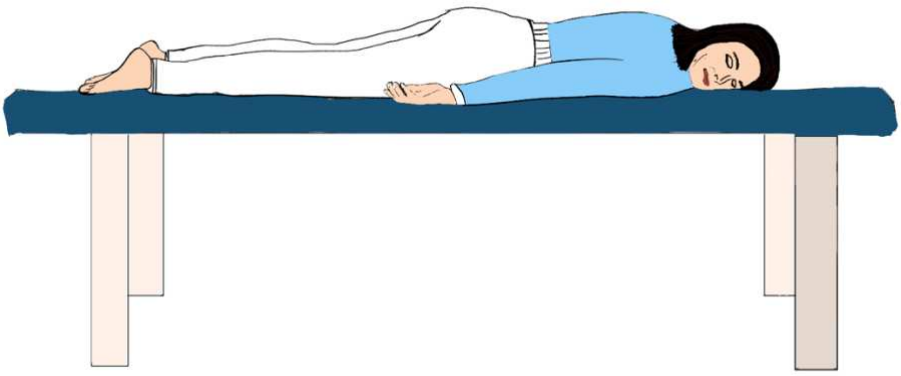
Figure 10. Heel Rise performance. A) back view stand phase; B) back view concentric transfer phase; C) back view mid phase; D) side view stand phase; E) side view concentric transfer phase; F) side view mid phase.

4.3.2 Muscle activity assessment

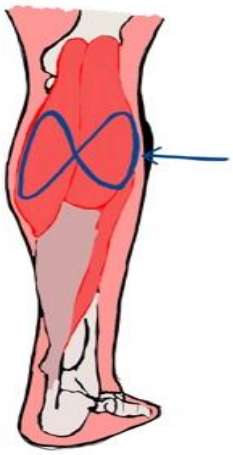
Data collection of calve muscle activity during static and dynamic postural stability tests was performed by surface electromyography (sEMG) by Trigno Sensors (Delsys Inc., Natick, USA) attached to the m. gastrocnemius vastus lateralis bilaterally (**Figure 8; 9; 10**) by experienced practitioner of the laboratory. After subjects' explanation and agreement, the place of sensor application was cleaned, shaved, and again cleaned with medical cleaning cloth (Medipal, Alcohol Wipes), consequently, the sEMG sensor was attached to measurement place by original adhesive stickers from Delsys manufacturer. sEMG activity was recorded simultaneously in all tests. Sample rate of recorded signal was set at 2048 Hz with a 16-bit A/D resolution. Bandwidth of sEMG sensors was high-passed (4^{th}-order Buterworth) at 20±5 hz and low-passed (4^{th}-order Buterworth) at 450±5 hz for further analysis (St. George et al., 2019; Germer et al., 2021). Further sEMG data analysis was performed by EMGworks Analysis software (Delsys Inc., Natick, USA). Recorded and filtered sEMG data underwent rectification to absolute values and enveloped by window length (root mean squared; RMS) of 200 ms (Farfan et al., 2010). For EMG activation normalization of DOM and NON lower limb individually, peak RMS muscle activity during flamingo tests (for dominant and nondominant individually) was used and applied to represent the mean RMS in percentages of sEMG activity during each test and each lower limb ($\%RMS_{max}$). Using unilateral standing on one leg (Flamingo) was preferred before maximal voluntary contraction (MVC) tests of calf muscles, in order to avoid excessive muscle excitation before and during static tests and before PT application. Carrying out the MVC tests on a different day than the subjects were tested was impossible due to the time constraints of this master's thesis.

4.3.3 Percussive therapy assessment

There was a pause (1:30min) between the 1^{st} and 2^{nd} measurements, during which the experimental group received triceps surae massage for 30s each. The percussive massage gun was set at 2100bpm and the pressure on the surface was 1 bar showed by the device, as indicated by the manufacturer.



11a)



11b)

Figure 11. 11a) the position probands took between the measurements. 11b) The blue line shows the direction of the massage using the PT.

During the massage the sEMG sensor were replaced for the easier access to the whole muscle group. After that it was attached to the same place as it was before. Putting it to the same spot was simplified by the fact there were visible pressure marks. The control group laid down to the same position as the experimental one and stayed like that for the same amount of time (1:30min). Afterwards they were tested once again.

4.4 Statistical analysis

The number of participants was determined using a power analysis with a predicted medium effect size – F2 = 0.15; with a significance level of $\alpha = 0.05$ and a test power of $1-\beta = 0.8$) to (n=44). Arithmetical means; standard deviations (±SD) and percentages were used within descriptive analysis. The normal data distribution assumption was performed by the Shapiro-Wilk test, and the homogeneity of variance assumption was performed by Bartlett's test. The significance of the difference between two and more factors was analyzed using the Multivariate Analysis of variance (MANOVA) with a confidence interval of 95%. The results of multiple comparisons were assessed using a post-hoc Mann-Whitney U test. Explanation of the proportion of factor variance (effect size) was evaluated by the Partial Eta Squared ($\eta p2$). The evaluated data were processed using MS Excel (Microsoft, USA) and IBM SPSS v25 (Statistical Package for Social Sciences, Inc., Chicago, IL, USA).

5 RESULTS

5.1 Pre-test results of the main groups

The **Table 6** discusses the individual differences between the tests taken by individuals in the two main groups. Basic descriptive analysis (mean and standard deviation) was performed for all tests used. Among the postural stability tests, we can observe a small test power (η2 = 0.01-0.06) only for open eyes (mm) (η2 = 0.01). In the group of HEALTHY subjects, we observed percentage (%) differences between specific parameters tested. OE vs. CE (17.85 ± 13.69%), Flamingo DOM vs. NON (15.60 ± 8.21%), OE DOM vs. NON (55.05 ± 36.85%), CE DOM vs. NON (49.09 ± 26.92%), Flamingo DOM stand vs. NON stand (22.96 ± 17.22%) and Heel Rise DOM vs. NON (32.94 ± 19.93%). Statistical analysis did not find any significant differences between postural stability parameters between CAI and HEALTHY subjects.

Table 6. Descriptive statistics for group for postural stability tests taken without the further distribution. (CAI – chronical ankle instability group, HEALTHY – healthy group)

	HEALTHY (n=21)		CAI (n=21)			
	Mean	Std. Deviation	Mean	Std. Deviation	Sig.	Partial Eta Squared
Open Eyes (mm)	156.19	28.02	162.62	46.11	0.59	0.01
Closed Eyes (mm)	177.48	35.92	174.14	49.89	0.81	0.00
Flamingo DOM (mm)	695.81	156.25	692.86	141.96	0.95	0.00
Flamingo NON (mm)	696.05	190.03	696.05	140.88	1.00	0.00

Legend: DOM – dominant lower limb; NON – nondominant lower limb

For the test using sEMG we observe Partial Eta Squared (small effect – (η2 = 0.01-0.06)) for open eyes DOM (η2 = 0.04), closed eyes DOM (η2 = 0.05), closed eyes DOM vs. NON (%) (η2=0.01), flamingo NON stand DOM air, flamingo NON stand NON stand, flamingo DOM stand NON air, flamingo DOM stand vs. NON stand (%) (η2=0.01). Heel rise DOM and heel rise NON (η2=0.02). In the CAI group, we observed percentage differences between specific tested parameters such as OE vs. CE (18.89 ± 15.84%), Flamingo DOM vs. NON (16.44 ± 9.04%), OE DOM vs. NON (55.14 ± 38.99%), CE DOM vs. NON (43.67 ± 28.63%), Flamingo DOM stand vs. NON stand (20.43 ± 19.23%) and Heel Rise DOM vs. NON

(48.07 ± 28.08%). Statistical analysis found significant difference (F=4,060; df=1; p=0.05; η2=0.1) between CAI and HEALTHY subjects in parameter of heel rise asymmetry between DOM and NON. Where HEALTHY subjects reached asymmetry of 32.94±19.94 % and CAI subjects 48.07±28.08 % in average (**Figure 12**). No other difference was observed between two groups within sEMG data before percussive therapy treatment.

Table 7. Descriptive statistics for group for sEMG tests taken without the further distribution. (CAI – chronical ankle instability group, HEALTHY – healthy group)

N=42	HEALTHY (n=21)		CAI (n=21)			
	Mean	Std. Deviation	Mean	Std. Deviation	Sig.	Partial Eta Squared
Open Eyes DOM	20.93	9.56	26.10	16.01	0.21	0.04
Open Eyes NON	22.04	15.82	23.15	17.87	0.83	0.00
Closed Eyes DOM	20.31	9.34	26.79	19.11	0.17	0.05
Closed Eyes NON	21.40	11.95	21.85	17.52	0.92	0.00
Flamingo NON stand DOM air	20.40	8.91	17.88	13.67	0.48	0.01
Flamingo NON stand NON stand	44.10	12.53	46.51	11.04	0.51	0.01
Flamingo DOM stand DOM stand	54.26	9.54	51.94	15.08	0.56	0.01
Flamingo DOM stand NON air	19.64	14.87	19.08	13.88	0.90	0.00
Heel Rise DOM	121.58	49.16	106.68	50.67	0.34	0.02
Heel Rise NON	135.76	60.46	117.08	63.27	0.33	0.02

Legend: Values are represented as % of maximal RMS during Flamingo stand (%RMS_{max}); DOM – dominant lower limb; NON – nondominant lower limb.

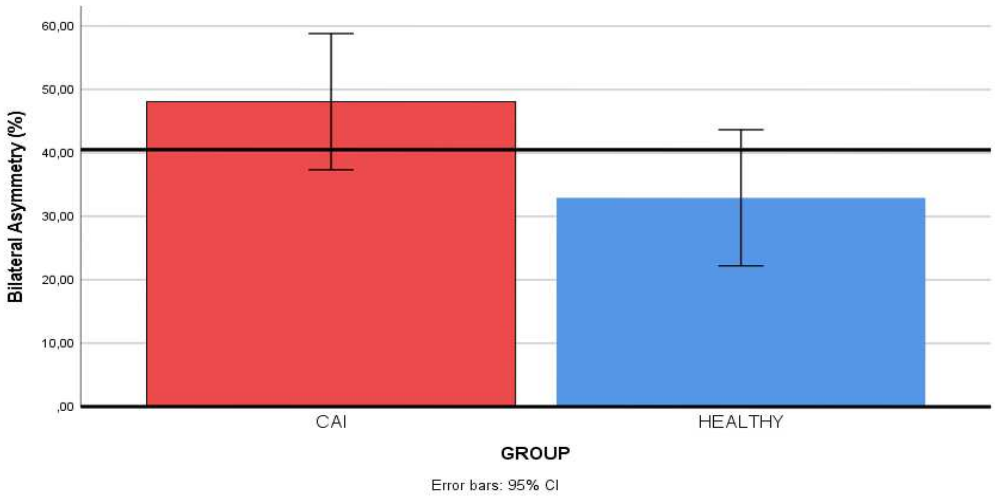


Figure 12. Bilateral EMG asymmetry between dominant and non-dominant lateral gastrocnemius of CAI and HEALTHY groups

5.2 Pre-tests vs. Post-tests results of postural stability

Tables 8 and **9** below highlight the differences between the analyzed groups. More pronounced, according to the data, are the standard deviations for the individual tests, where the CAI group showing even higher variability in the measured data. Higher standard deviations in CAI group can be explained by greater variability of the injury. The greatest improvement between pre and post-tests (-19,88%) was observed in the HEALTHY subjects using PT between measurements while testing the OE. Percussive treatment of HEALTHY YES POST showed significant improvement ($p=0.014$) in OE parameter when compared to CAI NO PRE ($p =0.014$) and CAI NO POST ($p=0.05$). Statistically better OE results was observed also in CAI YES POST after treatment, when compared to CAI NO PRE ($p=0.045$). Other groups were not statistically different before the PT application, and no other changes were evaluated significant between any groups in the OE parameter.

Effect of PT was also observed in the CE parameter, while only CAI YES POST (CE=138.40±24.48 mm) reached improvement ($p=0.05$) when compared to CAI NO POST (CE=187.64±124.90 mm). These groups have not differed statistically in pre-test results.

PT showed negative effect in the parameter of postural stability, more precisely in flamingo DOM vs. NON (%) in the HEALTHY YES group, which reached statistically higher ($p=0.014$) degree of bilateral asymmetry between dominant and non-dominant results in unilateral postural stability test flamingo (pre-test = 13.48±7.78% vs. post-test = 25.63±18.26%). This elevation in the mean bilateral asymmetry in flamingo test in HEALTHY YES POST reached also higher value as CAI NO POST (12.51±7.81%; $p=0.007$) and CAI NO PRE (13.94±10.96%; $p=0.015$). Experimental group of HEALTHY YES subjects did not show different ($p>0.05$) results in the pre-test values of the mentioned parameter with any group. No other PT significant effect was found between analyzed experimental or control groups within postural stability parameters of TTW.

In the HEALTHY NO PRE, we evaluated following percentage (%) differences between specific parameters tested. OE vs. CE (16.72 ± 14.77%), Flamingo DOM vs. NON (17.53±8.47%). In the post test without percussive

treatment, HEALTHY NO POST, reached similar, non-significant differences in-between measurements. Particularly OE vs. CE reached almost 20% (18.60±16.02%), and Flamingo DOM vs. NON almost 15% (13.94±10.96%). These differences have not shown statistical significance ($p>0.05$).

In the CAI NO PRE, we observed difference between OE vs. CE almost 20% (18.60 ± 16.02%), Flamingo DOM vs. NON (13.94 ± 10.96%). In the post tests, group reached higher, but not statistically different result in OE vs. CE (25.10 ± 48.63%) or Flamingo DOM vs. NON (12.51 ± 7.81%).

Table 8. Descriptive statistics for postural stability with the CON (control group), who didn't use the PT between the 1st and 2nd testing.

	HEALTHY NO PRE (n=11)		HEALTHY NO POST (n=11)		CAI NO PRE (n=11)		CAI NO POST (n=11)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Open Eyes (mm)	152.64	22.87	152.36	29.81	172.18	50.69	164.09	40.39
Closed Eyes (mm)	176.91	35.41	160.36	31.83	185.09	56.36	187.64	124.90
Flamingo DOM (mm)	711.45	126.07	649.00	162.67	739.00	141.79	727.09	165.40
Flamingo NON (mm)	679.00	153.07	682.73	209.63	707.64	153.73	713.09	198.36

Legend: DOM – dominant lower limb; NON – nondominant lower limb.

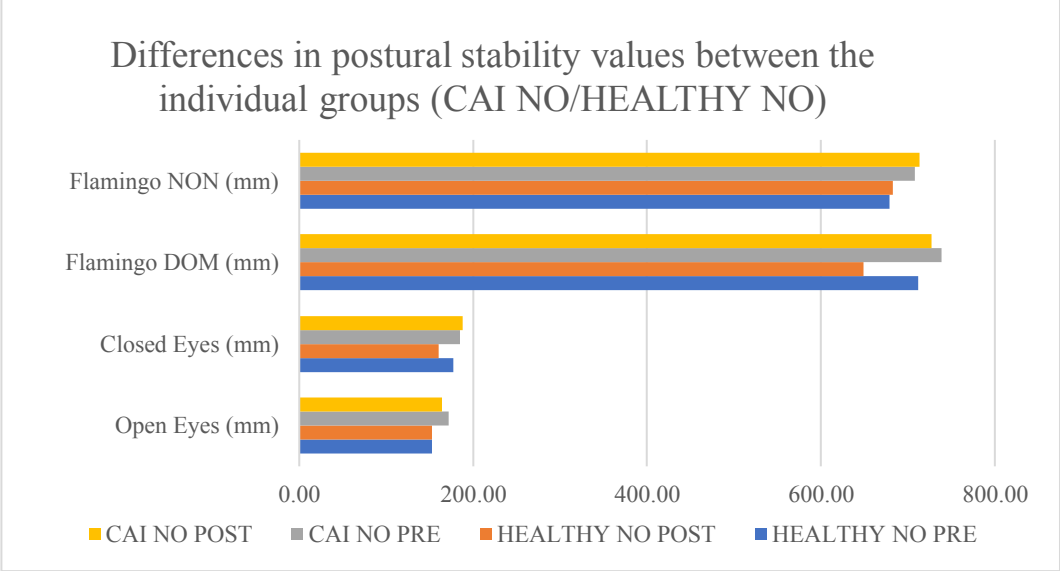


Figure 13. Differences in postural stability values between the control groups.

In the HEALTHY YES PRE group, we observed percentage differences between specific tested parameters such as OE vs. CE (19.08 ± 13.07%), Flamingo DOM vs. NON (13.48 ± 7.78%). In the HEALTHY YES POST, we observed percentage differences between specific tested parameters such as OE vs. CE (20.72 ± 16.46%), Flamingo DOM vs. NON (25.63 ± 18.26%). In the CAI YES PRE, we observed percentage differences between specific tested parameters such as OE vs. CE (19.21 ± 16.51%), Flamingo DOM vs. NON (19.19 ± 5.65%). In the CAI YES POST, we observed percentage differences between specific tested parameters such as OE vs. CE (7.71 ± 5.30%), Flamingo DOM vs. NON (16.32 ± 9.08%).

Table 9. Descriptive statistics for postural stability with the EXP (experimental group), which used the PT between the 1st and 2nd testing.

	HEALTHY YES PRE (n=10)		HEALTHY YES POST (n=10)		CAI YES PRE (n=10)		CAI YES POST (n=10)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Open Eyes (mm)	160.10	33.62	133.60	25.55	152.10	40.43	140.90	27.05
Closed Eyes (mm)	178.10	38.38	160.90	37.18	162.10	41.15	138.40	24.48
Flamingo DOM (mm)	678.60	189.65	625.00	189.36	642.10	130.31	692.00	144.60
Flamingo NON (mm)	714.80	231.23	690.80	233.35	683.30	132.29	629.50	192.81

Legend: DOM – dominant lower limb; NON – nondominant lower limb.

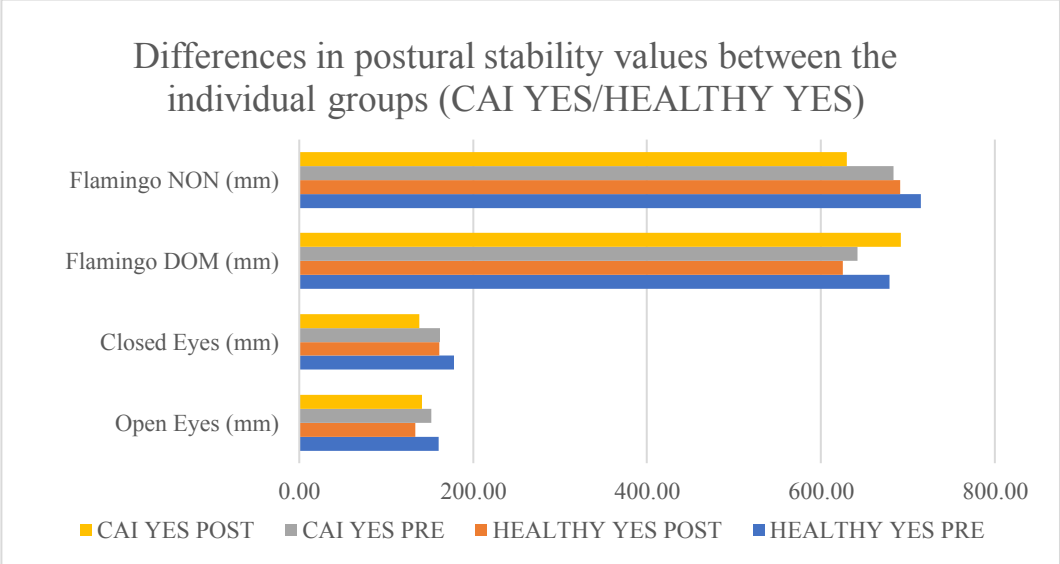


Figure 14. Differences in postural stability values between the experimental groups

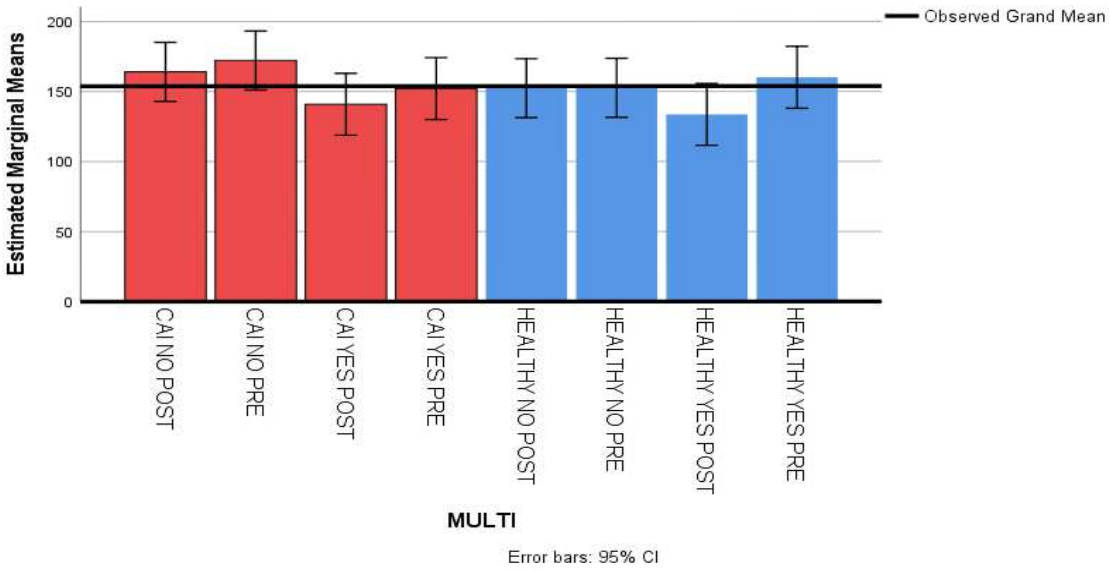


Figure 15. Estimated marginal means of open eyes (mm)

5.3 Pre-tests vs. Post-tests results of sEMG

Tables 10 and **11** below highlight the differences between the groups considering the sEMG data. The comparison between the groups is shown in the **Figure 16**. In the HEALTHY NO PRE, we observed percentage (%) differences between specific parameters tested OE DOM vs. NON (53.61 ± 41.20%), CE DOM vs. NON (42.56 ± 26.07%), Flamingo DOM stand vs. NON stand (23.31 ± 17.51%) and Heel Rise DOM vs. NON (38.95 ± 21.02%).

All analyzed groups have showed slightly higher, but non-significantly different ($p>0.05$) bilateral asymmetry (between DOM and NON) in muscle activation during OE in post-test, but only CAI YES POST (72.52±42.31%) reached significantly higher ($p=0.041$) result in post-test after PT treatment when compared to CAI NO PRE (47.94±39.67%). CAI YES PRE did not differ with any group before PT application.

In the HEALTHY NO POST, we observed percentage (%) differences between specific parameters tested. OE DOM vs. NON (66.5 ± 49.82%), CE DOM vs. NON (52.41 ± 45.14%), Flamingo DOM stand vs. NON stand (30.10 ± 23.92%) and Heel Rise DOM vs. NON (54.00 ± 69.35%). In the CAI NO PRE, we observed percentage (%) differences between specific parameters tested OE DOM vs. NON (47.94 ± 39.67%), CE DOM vs. NON (38.08 ± 27.53%), Flamingo DOM stand vs. NON stand (26.21 ± 21.03%) and Heel Rise DOM vs. NON (47.10 ± 29.46%). In

the CAI NO POST, we observed percentage (%) differences between specific parameters tested. OE DOM vs. NON (65.25 ± 47.93%), CE DOM vs. NON (49.55 ± 29.68%), Flamingo DOM stand vs. NON stand (30.49 ± 26.23%) and Heel Rise DOM vs. NON (54.22 ± 39.40%).

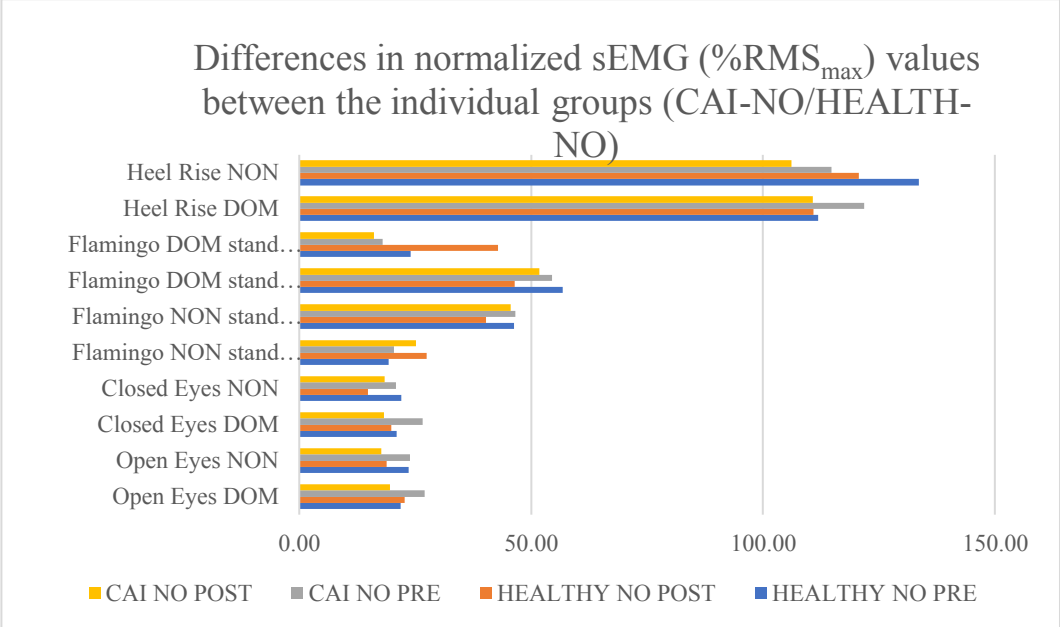


Figure 16. Differences in normalized sEMG values between the CAI/HEALTHY NO groups *Legend: Values are represented as % of maximal RMS during Flamingo stand (%RMS$_{max}$); DOM – dominant lower limb; NON – nondominant lower limb.*

Table 10. Descriptive statistics for the control group in sEMG testing.

n=22	HEALTHY NO PRE (n=11)		HEALTHY NO POST (n=11)		CAI NO PRE (n=11)		CAI NO POST (n=11)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Open Eyes DOM	21.79	10.29	22.71	13.57	27.07	17.45	19.56	15.04
Open Eyes NON	23.54	16.50	18.86	13.05	23.91	21.75	17.67	15.26
Closed Eyes DOM	21.03	10.11	19.91	11.75	26.56	19.26	18.25	12.45
Closed Eyes NON	22.03	10.69	14.87	8.52	20.82	19.38	18.36	15.05
Flamingo NON stand DOM air	19.29	9.28	27.40	18.12	20.37	14.60	25.16	26.68
Flamingo NON stand NON stand	46.31	9.83	40.31	12.77	46.60	12.64	45.62	16.10
Flamingo DOM stand DOM stand	56.82	10.56	46.40	27.00	54.58	15.54	51.84	20.16
Flamingo DOM stand NON air	24.08	17.35	42.79	50.83	17.97	13.29	16.08	11.31
Heel Rise DOM	111.89	50.91	110.87	60.95	121.77	58.16	110.75	59.29
Heel Rise NON	133.65	64.91	120.61	62.30	114.76	75.39	106.20	77.57

Legend: Values are represented as % of maximal RMS during Flamingo stand (%RMS_{max}); DOM – dominant lower limb; NON – nondominant lower limb.

In the HEALTHY YES PRE group, we observed percentage differences between specific tested parameters such as OE DOM vs. NON (56.63 ± 33.56%), CE DOM vs. NON (56.26 ± 27.31%), Flamingo DOM stand vs. NON stand (22.57 ± 17.83%) and Heel Rise DOM vs. NON (26.33 ± 17.29%). In the HEALTHY YES POST, we observed percentage differences between specific tested parameters such as OE DOM vs. NON (55.29 ± 39.39%), CE DOM vs. NON (55.52 ± 23.76%), Flamingo DOM stand vs. NON stand (33.86 ± 31.66%) and Heel Rise DOM vs. NON (18.67 ± 13.54%). In the CAI YES PRE, we observed percentage differences between specific tested parameters – OE DOM vs. NON (63.05± 38.69%), CE DOM vs. NON (49.81 ± 29.99%), Flamingo DOM stand vs. NON stand (14.07 ± 15.65%) and Heel Rise DOM vs. NON (49.15 ± 28.02%). In the CAI YES POST,

we observed percentage differences between specific tested parameters such as OE DOM vs. NON (72.52 ± 42.31%), CE DOM vs. NON (66.87 ± 37.49%), Flamingo DOM stand vs. NON stand (33.42 ± 27.63%) and Heel Rise DOM vs. NON (66.91 ± 58.53%).

Table 11. Relative percentage sEMG values in experimental groups.

N=20	HEALTHY YES PRE (n=10)		HEALTHY YES POST (n=10)		CAI YES PRE (n=10)		CAI YES POST (n=10)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Open Eyes DOM	19.99	9.15	22.71	9.40	25.04	15.11	26.73	26.99
Open Eyes NON	20.40	15.74	24.26	22.30	22.30	13.53	28.69	34.12
Closed Eyes DOM	19.51	8.87	21.73	8.27	27.04	19.99	30.59	26.88
Closed Eyes NON	20.71	13.77	20.68	18.18	22.97	16.19	26.38	24.62
Flamingo NON stand DOM air	21.61	8.82	19.95	6.95	15.14	12.73	22.16	24.45
Flamingo NON stand NON stand	41.66	15.13	48.57	28.09	46.41	9.64	54.76	36.51
Flamingo DOM stand DOM stand	51.43	7.84	45.43	10.44	49.04	14.81	47.05	20.09
Flamingo DOM stand NON air	14.77	10.33	21.73	19.22	20.31	15.12	24.12	29.46
Heel Rise DOM	132.23	47.42	132.46	56.65	90.09	36.91	79.66	35.64
Heel Rise NON	138.09	58.57	142.68	70.16	119.64	50.65	112.32	47.14

Legend: Values are represented as % of maximal RMS during Flamingo stand (%RMS$_{max}$); DOM – dominant lower limb; NON – nondominant lower limb.

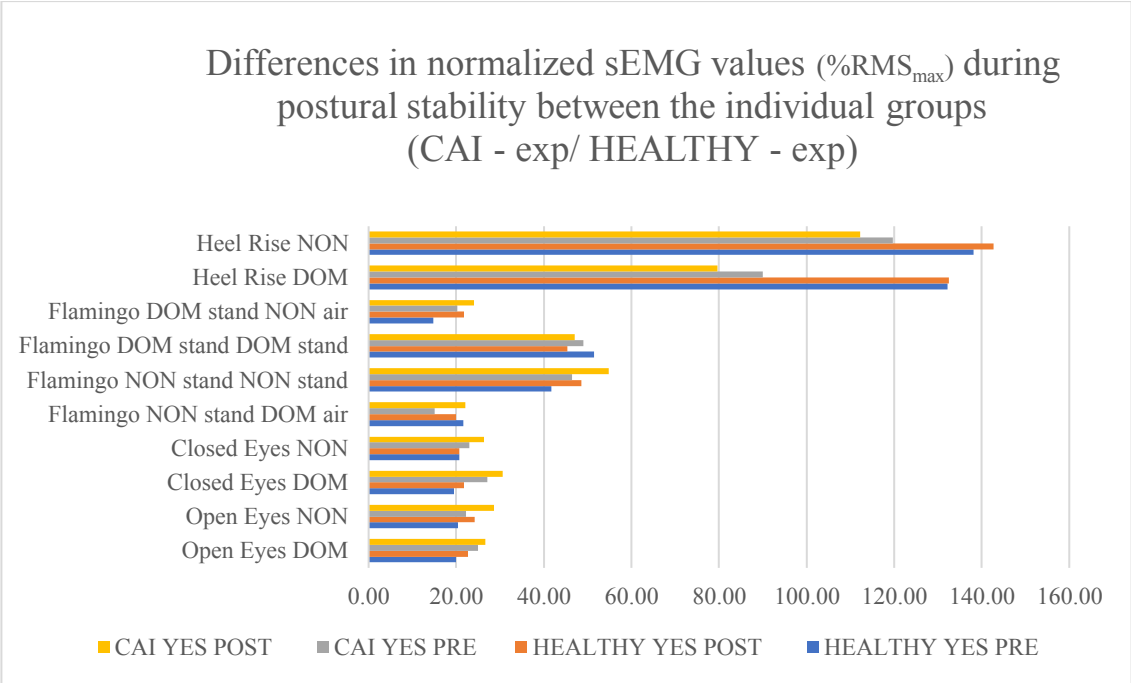


Figure 17. Differences in postural stability between the CAI/HEALTHY EXP groups

5.4 Post-hoc results

We did the post-hoc statistical analysis for all the groups we measured. Those mentioned bellow we found as statistically significant ($p \leq 0{,}05$).

5.4.1 Postural stability – open eyes

In the post-hoc results we aimed specifically for the statistically significant differences, which are also mentioned in these results. Between the CAI NO PRE (CNP) and HEALTHY YES POST (HYPO) we found the mean difference (MD) 38.582 ($p=0.014$) and CNP vs. CAI YES POST (CYPO) was the MD 31.282 ($p=0.045$). The values of specific groups are mentioned in the **Figure 18** below.

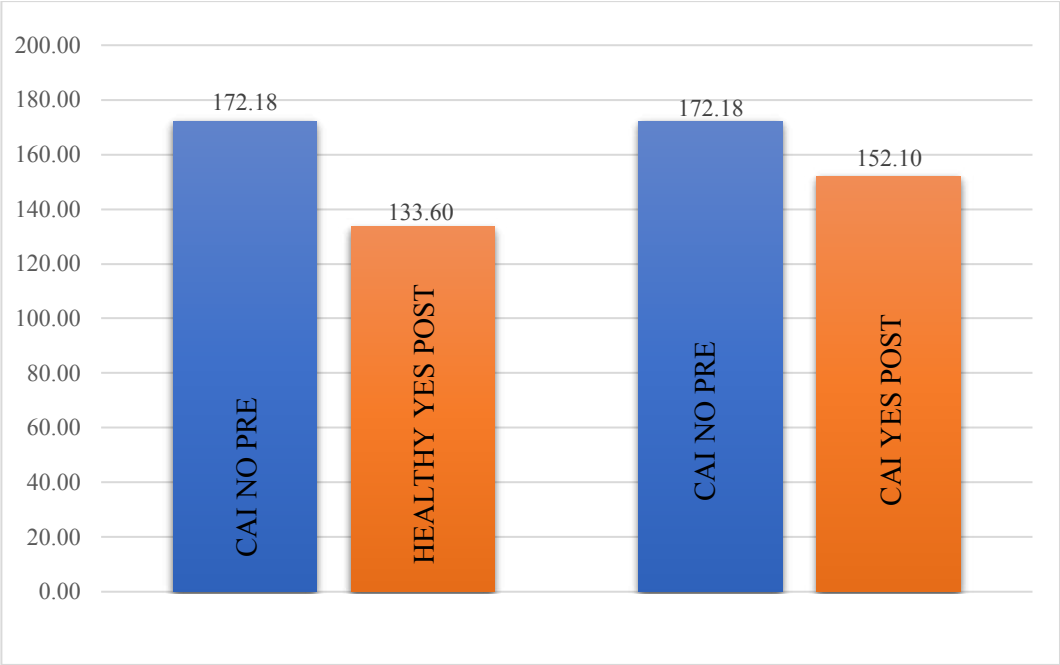


Figure 18. Difference between groups when measuring postural stability with OE. Shown pairwise comparisons (CNP vs. HYPO) and (CNP vs. CYPO) were calculated as statistically significant ($p<0.05$). Values are represented as (*mm*).

We also observed the significant difference even between the groups post PT (**Figure 19**) – specifically between the CAI NO POST (CNPO) vs. HYPO we found the MD of 30,491 (p=0,05).

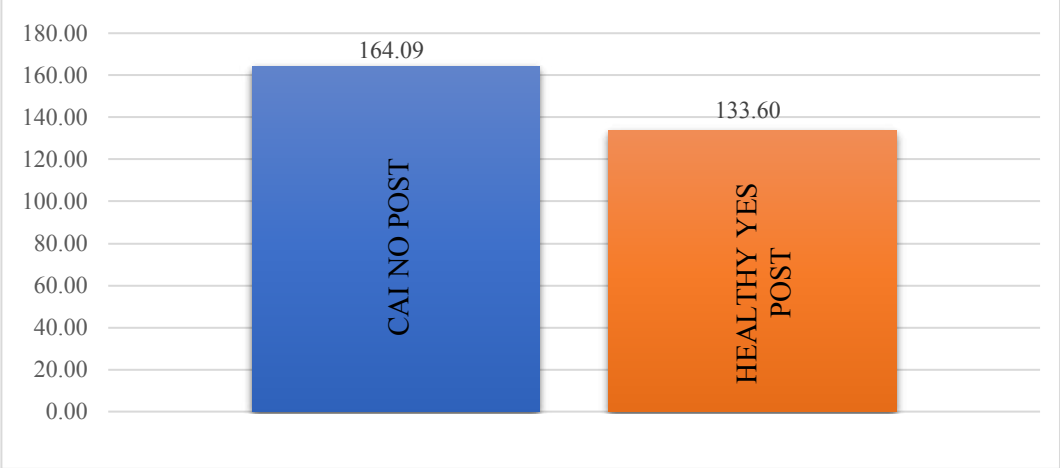


Figure 19. Difference between groups when measuring postural stability with OE. Shown pairwise comparisons (CNPO vs. HYPO were calculated as statistically significant ($p<0.05$). Values are represented as (*mm*).

5.4.2 Postural stability – closed eyes

In the CE test the only significant difference was evaluated between the CNPO and CYPO where we found the MD=49.24 (p=0.05). Exact values of the mentioned measured parameters are in the **Figure 20**.

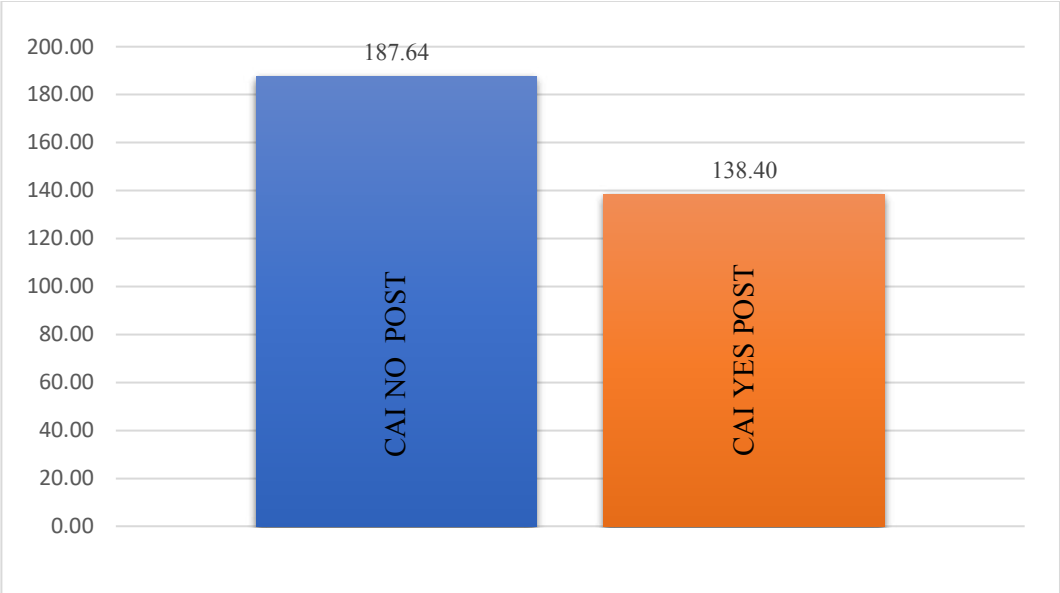


Figure 20. Difference between groups when measuring postural stability with CE. Shown pairwise comparisons (CNPO vs. HYPO) were calculated as statistically significant ($p<0.05$). Values are represented as (*mm*).

5.4.3 sEMG – flamingo DOM vs. NON (%)

In the flamingo DOM vs. NON test we found 5 of significant differences of following groups. Between the HYPO and CNPO we found the MD 13.122% (p=0.007), HYPO vs. HYP was the MD 12.156% (p=0.014), HYPO vs. CNP was the MD 11.689% (p=0.015), HYPO vs. CYPO was the MD 9.313% (p=0.05). In all cases, the values of healthy subjects were higher than those of the CAI group. The specific values measured in each group are mentioned in the **Figures** (**21**; **22**).

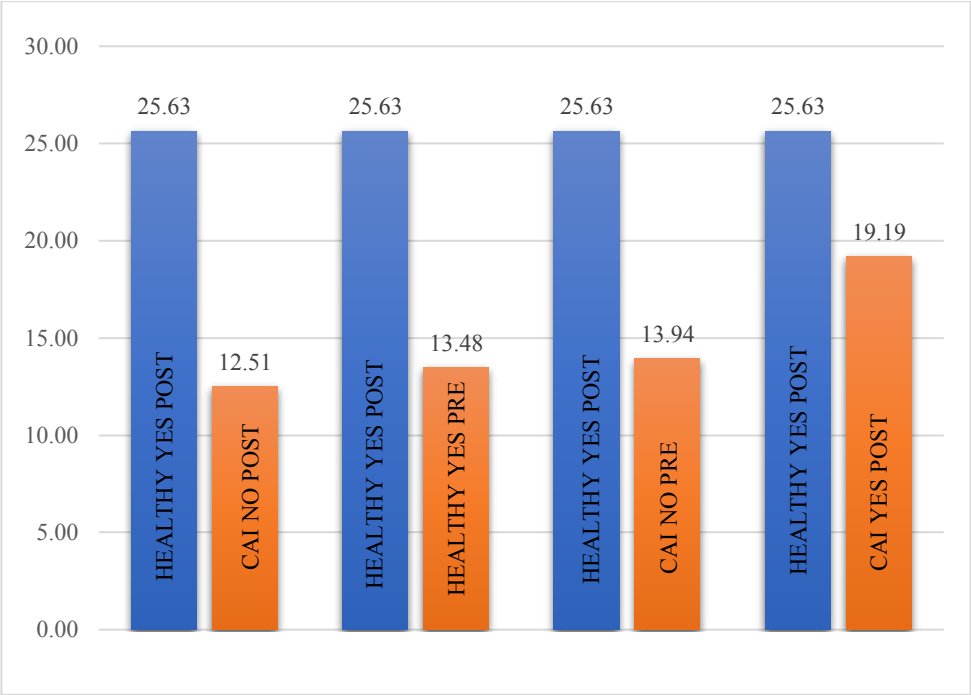


Figure 21. Difference between groups when measuring EMG (flamingo test – difference between the DOM and NON in %). Shown pairwise comparisons (HYPO/CNPO; HYPO/HYP; HYPO/CNP; HYPO/CYPO) were calculated as statistically significant ($p<0.05$).

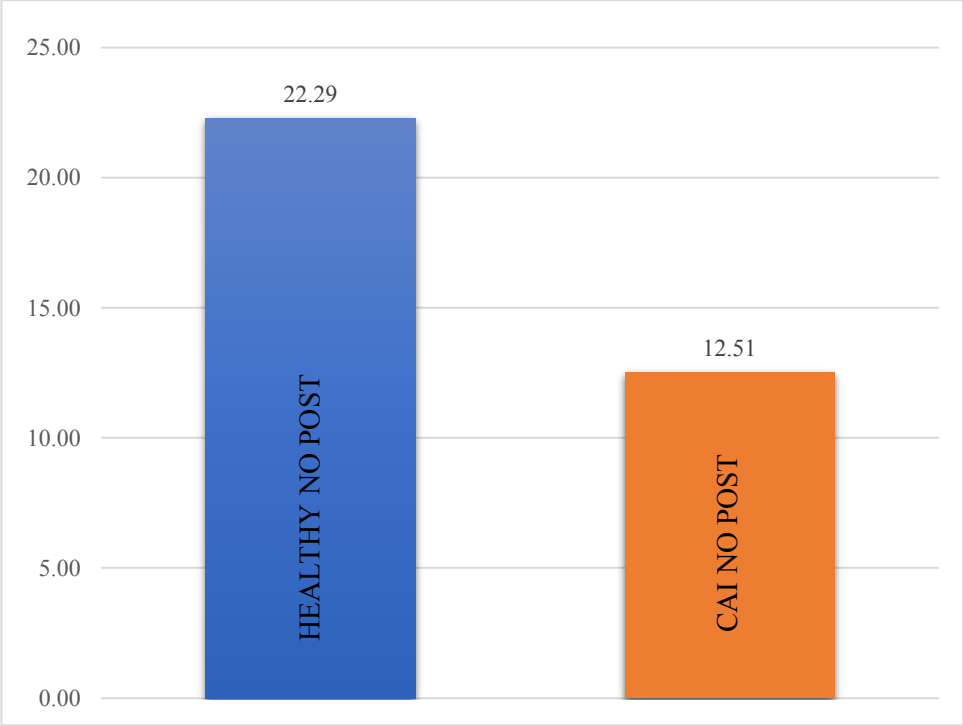


Figure 22. Difference between groups when measuring EMG (flamingo test – difference between the DOM and NON in %). Shown pairwise comparisons (HNPO/CNPO) were calculated as statistically significant ($p<0.05$).

5.4.4 sEMG – open eyes – DOM vs. NON (%)

After the use of PT, the difference between DOM and NON has got even higher in subjects with CAI. Statistical difference was found primarily between the CYPO and CNP where we found the MD 24,58 % (p=0.041). The specific values measured in each group are mentioned in the **Figure 23**.

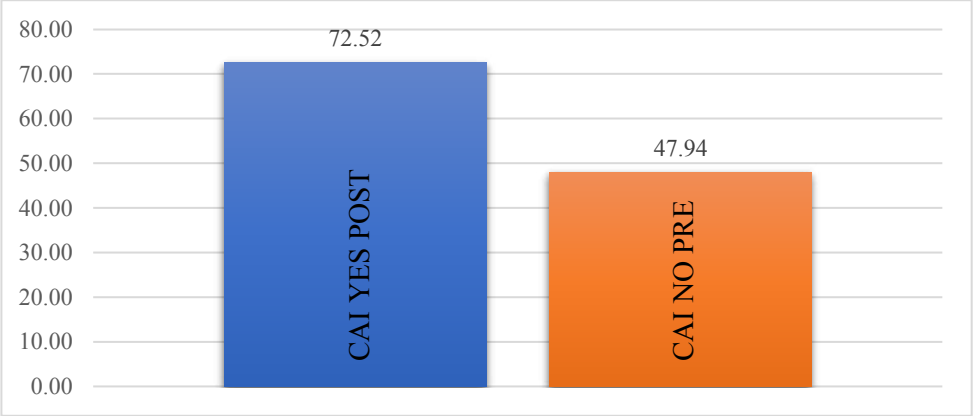


Figure 23. Difference between groups when measuring EMG (OE – difference between the DOM and NON in %). Shown pairwise comparisons (CYPO/CNP) were calculated as statistically significant ($p<0.05$).

5.4.5 sEMG – flamingo DOM stand NON air

In the unilateral flamingo test, we found the statistical differences between almost every single group (except for CYPO) compared to the HNPO group, which got its values higher than everybody else during post-test. However, we were able to find out the differences between the HNPO and HYP where we found the MD 28.018% RMSmax (p=0.011), HNPO and CNPO – MD 26.710 $RMS_{max\%}$ (p=0.013), HNPO and CNP was the MD 24.824 $RMS_{max\%}$ (p=0.021), HNPO vs. CYP was the MD 22.483 $RMS_{max\%}$ (p=0.04), HNPO vs. HYPO 21.064 $RMS_{max\%}$ (p=0.05). Altogether were the results compared in the **Figure 24**. These results were unclear, as we found higher $\%RMS_{max}$ in the lower limb that was in the air during unilateral stand, and only in one group.

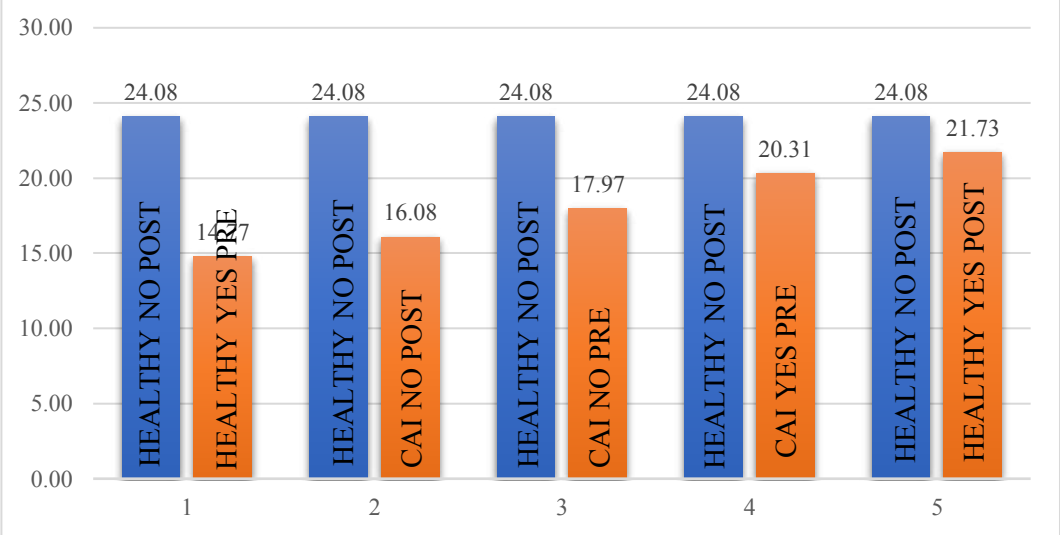


Figure 24. Difference between groups when measuring EMG (FLAMINGO – DOM STAND NON AIR) Shown pairwise comparisons (HNPO/HYP; HNPO/CNPO; HNPO/CNP; HNPO/CYP; HNPO/HYPO) were calculated as statistically significant ($p<0.05$). Values are represented as %RMSmax.

5.4.6 sEMG – heel rise DOM

In the dynamic bilateral postural stability test (Heel Rise) we set the sEMG to find out the muscle activity of the m. gastrocnemius vastus lateralis. In the mentioned measured parameters, we observed the statistically significant difference between the CYPO, HYPO, and HYP where even after PT use, we found lower values of muscle activity in CAI subjects. Precisely the mean difference was 52.799 $RMS_{max\%}$ (p=0.026) in CYPO/HYPO, and 52.576$RMS_{max\%}$ of mean difference (p=0.026) in CYPO/HYP. Specific values are mentioned in the **Figure 25**.

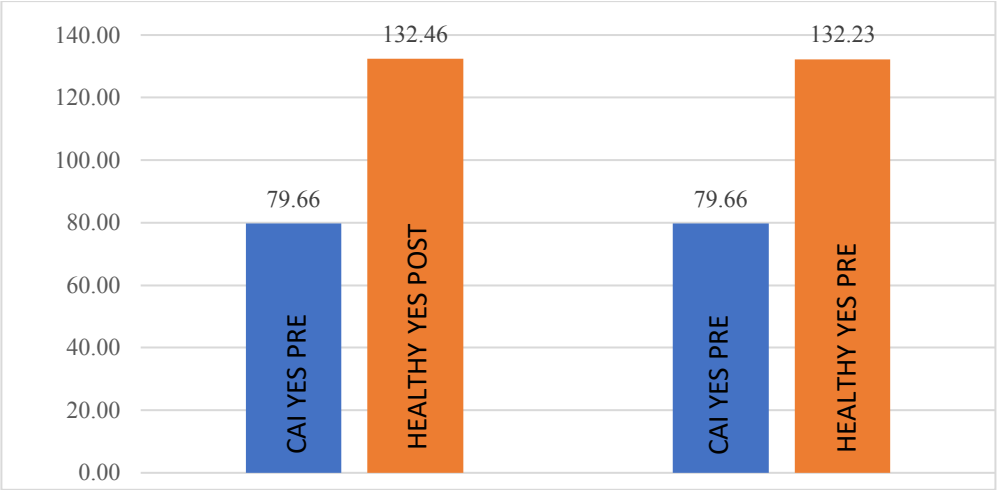


Figure 25. Difference between groups when measuring EMG (HEEL RISE DOM). Shown pairwise comparisons (CYPO/HYPO; CYPO/HYP) were calculated as statistically significant ($p<0.05$). Values are represented as $RMS_{max\%}$.

Last but not least, we found the difference between CNP and CYPO (p=0,067) which can be considered as a value tending towards a significant change of muscle activity after PT use. Specific values measured are mentioned in the **Figure 26** below.

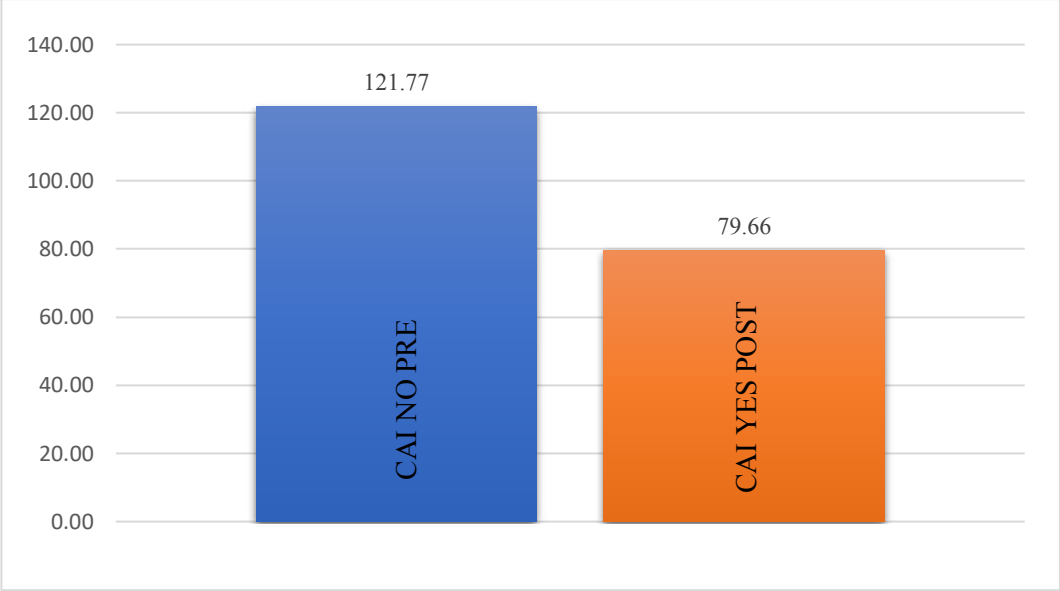


Figure 26. Difference between groups when measuring EMG (HEEL RISE DOM). Shown pairwise comparisons (CNP vs. CYPO) measured p=0,067. Values are represented as $RMS_{max\%}$.

5.4.7 sEMG – heel rise DOM vs. NON (%)

There were observed even significant differences between the muscle activity in the heel rise when comparing the dominant and non-dominant leg. From the data below (**Figure 26**; **27**) we were able to spot much higher asymmetry from the subjects with CAI. Especially when comparing the CYPO and HYPO, where we found the MD 48.234% (p=0.008), CsNPO and HYPO where the MD was 35.544% (p=0.043). HNPO and HYPO – MD 35.331% (p=0.043), and CYPO and HYP where the MD was 40.576% (p=0.025). The only group from HEALTHY subjects with relatively high asymmetry was HNPO (54%).

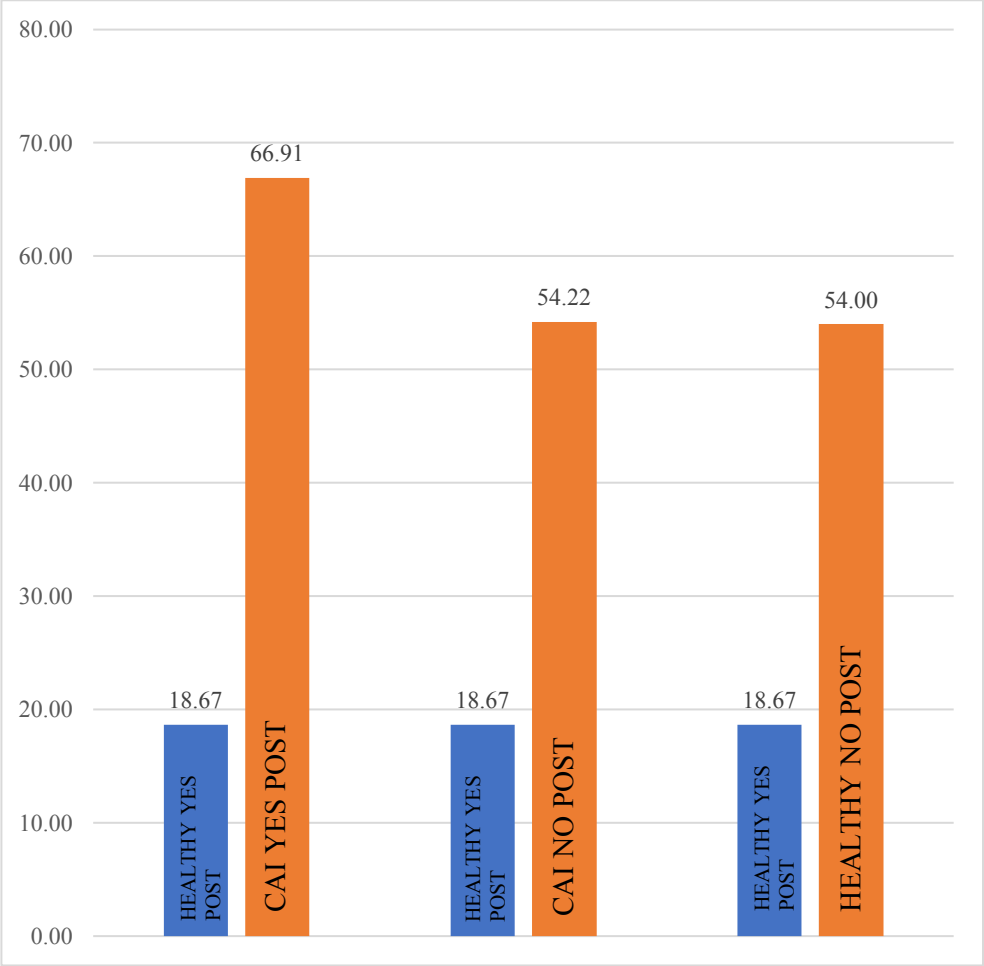


Figure 27. Difference between groups when measuring EMG (HEEL RISE DOM vs. NON (%)). Shown pairwise comparisons (HYPO/CYPO; HYPO/CNPO; HYPO/HNPO) were calculated as statistically significant ($p<0.05$). Values are represented as %.

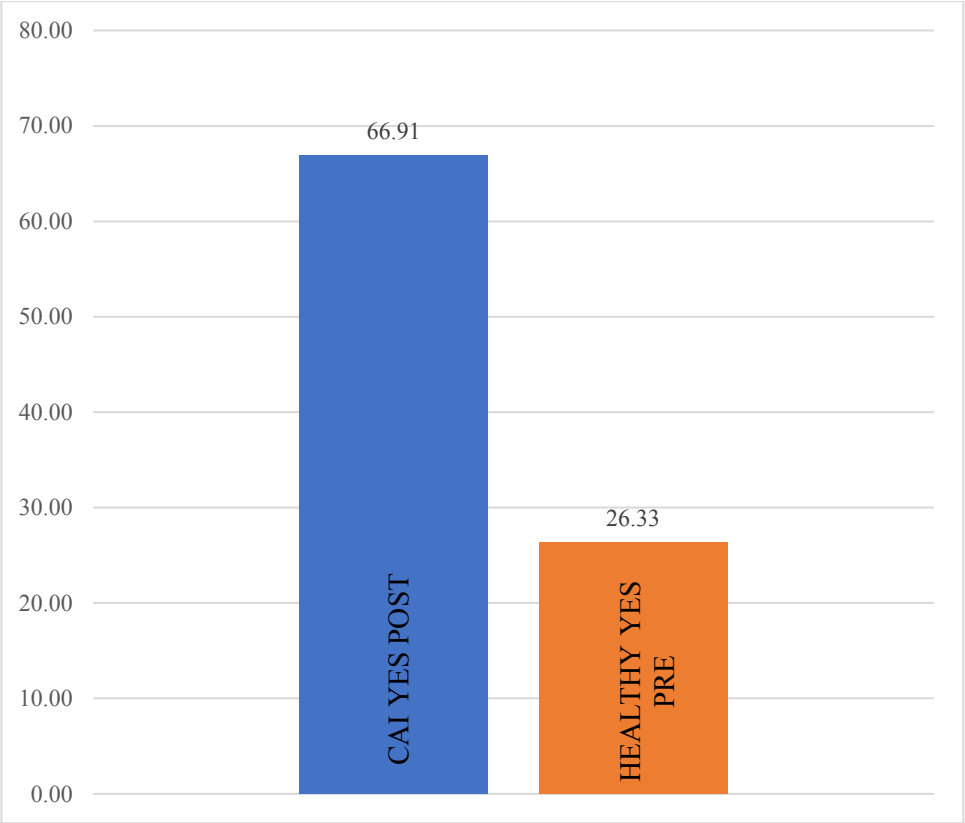


Figure 28. Difference between groups when measuring EMG (HEEL RISE DOM vs. NON (%)). Shown pairwise comparisons (CYPO/HYP) were calculated as statistically significant ($p<0.05$). Values are represented as %.

6 DISCUSSION

One of the most important findings of this master thesis was that we found higher calf muscle activation asymmetry between the dominant and non-dominant lower limb in heel rise performance in CAI subjects when compared to HEALTHY ($p \leq 0.05$). CAI subjects reached almost 50% asymmetry during heel rise performance in average, while HEALTHY subjects reached approximately 30%. Both groups showed higher muscle activation in nondominant lower limb, but no statistical difference was found between dominant and nondominant limb. This may confirm the fact from the literature search referring to a significant deficit in balance and muscle activity in the affected ankle (Brown et al., 2007). However, approximately 50% of our CAI subjects have reported both lower limbs with injury history. During the research, a total of 8 measurements containing static and dynamic tests focusing on postural stability on one and two legs were performed on 42 subjects in total. The measurements were carried out on 4 dates in the morning (8am-12pm) in the laboratory at UK FTVS. Constant room temperature was ensured. Using sEMG, we monitored the activity of m. gastrocnemius vastus lateralis. The placement of the electrodes on the vastus lateralis was chosen due to a smaller cross-sectional area than the vastus medialis in general and thus a possible larger muscle crosstalk on the m. soleus. Kiung-min et al. (2012) proved that it is the muscle activity of m. soleus that is reduced in people with CAI from the interpretation of the Mmax:H_{max} ratio.

The original thesis of our work assumed the acute effect of percussive therapy on enhancing postural stability performance due to higher activity of the treated muscle due to the amplitude and force mechanically transmitted to the muscle providing proprioception increasing muscle tone. In other words, they increase the response of muscle spindles that excite Ib nerve fibers. Through their activation, we should be able to increase neurotransmitter activity by a Ca-dependent mechanism as a consequence of depolarization of the axon terminal membrane and thus improve neuromuscular activation. Chronic pathological differences in organism cause cortical neuroplasticity, which usually result in neurological changes. Hass et al. (2010) demonstrated the altered supraspinal motor control mechanisms. Those changes were afterwards described even on deeper level

of neural system when Xie et al. (2022) confirmed voxel-based correlation with brain plasticity in parahippocampal and left postcentral areas of patients with CAI. The somatosensory cortex (including the postcentral gyrus) is known for proprioception, which can partly explain the topic.

Although the inhomogeneity of the probands was supposed at the outset and the inclusion parameters in the selection into the experimental group could have been more specific, we excluded cohort of people who did exhibit threshold values in the Gaussian distribution of our measurements, including professional athletes.

The results show that the application of PT caused probands with CAI (CYPO) to have on average lower values in the postural stability test with eyes open – M of TTW=140.9 mm, than the group not using PT (CYP) which reached values – M of TTW =172 mm in the same test. Their MD was therefore determined to be 31.282 (p=0.045). Similar findings can be observed in the testing of postural stability with closed eyes tests, where CAI patients in the experimental group (CYPO) achieved lower values (M of TTW =138.4mm), while the group not using PT (CNPO) achieved higher values in the same test (M of TTW =187.64mm). Their MD was therefore determined to be 49.236mm (p=0.05). We were also able to observe a significant difference between CNP (M of TTW = 172 mm) and HYPO (M of TTW = 133 mm); MD was 38.582mm (p=0.014), as well as CNPO (M of TTW = 164 mm) vs. HYPO (M of TTW = 133mm) in the open eye tests (MD = 30,491mm; p=0.014). It is also useful for our work that there were no significant differences between the postural stability tests in CNP/CNPO versus HYP/HNP, which would indicate already significant changes without the use of PT. The theory that percussive therapy could influence postural stability in patients with CAI is supported in this case by the fact that we found no statistically significant differences between the control and experimental groups of healthy probands.

The issue of postural stability can be considered as a multifactorial and as a multigaspable topic in context to the levels addressed. From a biomechanics perspective, we take postural stability as a mixture of numbers comprising precise movement of the sole of the foot, weight distribution, center of pressure (COP), COM, AC, AS, BS, etc. from which, of course, with relatively high precision, one can subtract the movement along the FootScan and make a verdict of the level of postural stability based on these data.

However, from the kinesiological/physiotherapeutic point of view we must also consider the involvement of kinematic chains, different compensatory strategies, the level of motor skills, the overall physical readiness of the person, the physiological or pathophysiological state of the CNS and the sporting history of the tested person. Lopez-Valenciano et al. (2019) confirmed some parameters showing correlation with dynamic stability, such as knee flexion and extension strength, isometric hip abduction, adduction strength, lower extremity ROM (ankle, knee, hip) as well as core strength for male (R^2=23.1 for DOM and R^2=33.5 for NON) and female (R^2=38.2 for DOM and R^2= 46.9 for NON leg).

In FLAMINGO tests with ratio between DOM and NON-dominant leg (expressed in %), we observed a greater difference in healthy subjects (significant differences compared to other groups was in range from 22.29 - 25.63%), while the CAI group had a percentage difference of almost half in most significant difference cases (values ranging from 12,51 - 13.94%). All values regardless of significance was in healthy subjects 13.48-25,63%. In CAI group was all values regardless of significance measured from 12.51-19.19%. Based on the initial history of the probands, in most cases the dominant leg matched the affected leg. Most studies indicate a non-significant difference ($p>0.05$) between postural stability when standing on the dominant versus non-dominant lower limb when probands are not professional athletes (Hoffman et al., 1998; Alonso et al., 2011; Karakaya et al., 2015). On the contrary, professional athletes such as tennis players, handball players, volleyball players, and soccer players often show better ($p<0.05$) stability on the non-dominant leg due to motor habituation (Ricotti and Ravaschio, 2011; Barone et al., 2011; Ricotti et al., 2013; Kartal, 2014; Marchetti et al., 2014).

When dynamic postural stability and specific activity of m. gastrocnemius vastus lateralis were investigated, we observed significant differences in DOM in the heel rise test. Despite a slightly lower mean values of muscle activation of dominant lower limb during heel rise in CAI groups compared to HEALTHY groups, only significantly lower activity was found when CYPO (79.66 $\%RMS_{max}$) was compared to HEALTHY subjects in pre-test (132.46 $RMS_{max\%}$) and post-test (132.23 $RMS_{max\%}$). Measured mean difference was MD=52.799% (p=0.026) in CYPO/HYPO and MD=52.576% (p=0.026) or HYP/CYPO, again representing a confirmation of the previous theoretical basis that patients with CAI have reduced

neuromuscular activity. There was a significant difference when comparing dominant and non-dominant leg (in %) while heel rise test only when comparing HYPO (18.67 %) with CNPO (54.22%; MD=35.544; p=0.043), CYPO (66.91%; MD=48.234; p=0.008) and HNPO (54%; MD=35.331; p=0.044). Also, we found the difference between the HYP (26.33%) and CYPO (66.91%; MD=40.576; p=0.025).

One reason for not demonstrating differences between HYP vs HYPO may be the improved ability to facilitate and therefore "activate" compared to the CAI group. Considering the kinematic chain, in CAI patients was proved lower muscle activity on m. gluteus medius, maximus and hamstrings compared to controls (Webster, Gribble, 2013). Also Feger et al. (2014) mentioned significantly moderate to large dicreases of EMG activity in lower extremity muscle.

Thus, our results didn't show the significant differences between at least same group using the PT and certainly not the CAI group.

Although our work focused on a very narrowly specified topic, a relatively large number of scientific questions related to PT have already been investigated. Most of them deal with the issue of increasing range of motion or explosive muscle strength, all in most cases in performance athletes. Along with PT, the reduction of chronic musculoskeletal pain is then inflected across all age categories and predominantly the general, non-sporting population. At the CAI level, the scientific community is predominantly concerned with treatment options and their efficacy, understanding the pathomechanics of LAS and the potential for prevention.

A fundamental pillar is already repeatedly confirmed neural delay in people with CAI. Van Deun et al. (2007) confirmed a delay in the onset of muscle activation not only at the ankle level but also in more proximal parts of the body and a less variability and lower activation patterns compared to a healthy group. This statement can be supported by Fatima et al., (2020) who described and proved diminished muscle activity of m. gluteus maximus et medius in people with CAI ($p \leq 0{,}001$).

Thus, we believe that the issue of CAI is a more complex problem from a therapeutic point of view and its solution does not fall by localization only to the area around the ankle. Related to this is the fact that different movement strategies

for gaits have been confirmed in people with CAI. Son et al. (2017) found a significant difference in CAI patients compared to healthy in adopted landing positions. Such as less plantarflexion, more knee and hip flexion. Which may indicate an already preserved change in movement pattern and "relieving" the ankle complex as a variant of preventing further injury.

The solution can be conservative (surgical treatment-reattaching or imbricating injured native tissues or replacing ligaments with autologous or allograft tissue (Camacho et al., 2019)), but a few authors have found a modest effect using neuromuscular training (O'Driscoll et al., 2011; Kim et al., 2017). People with CAI suffer from proprioceptive deficits (Xue et al., 2021), which may be partly addressed by neuromuscular (proprioceptive) stimuli. In practical use neuromuscular training is more relevant to professional and performance athletes. For the non-sporting population, more conservative and less demanding solutions are the most friendly option. Such as kinesio-taping in the meta-analysis (of 8 studies) by Biz et al. (2022) confirmed significant improvements in CAI patients using in biomechanical gait function (stride length, stride velocity) and reduction in ankle ROM (inversion/eversion). This therapy did not have a significant effect in Star Excursion Balance Test (SEBT) ($p>0.05$) compared to untaped subjects (Hettle et al., 2013).

However, the muscle activation is mentioned by the manufacturer as a real benefit, it seems like this thesis is the first one to deal with this kind of problem. Most of the studies using the PT is focusing on decreasing the pain, lowering the delayed onset muscle soreness (DOMS) and increasing the range of motion. Imtiyaz et al. (2014) proved that muscle soreness was significantly lower in PT compared to control group. The parametres were measured in 3 different times (24; 48 and 72 hours) with a significant difference in all of them. As in the functional view Martin (2021) stated PT is the most effective in increasing lower limb range of motion when compared to foam rolling and other self-myofascial releasing techniques.

In the context of the issue at hand, this work could therefore be classified as a relatively new category in the field of research, despite the fact that muscle activation is a topic that has been discussed by manufacturers. Thus, the expansion of this topic, not only in the context of CAI, can be the subject of further research

enriched with additional parameters investigated and generalization to a broader population.

As a main study limitation, we consider wide heterogeneity of subjects within the groups. As already mentioned, even though we tried to eliminate subjects with high sports experience and people whose motor patterns are directed predominantly unilaterally, there was people with high physical activity per week, which can probably affect the results of postural stability and even muscle activation. Another study limitations were including only 44 subjects (consequently divided to four groups by approximately 10 subjects per group) after the power analysis results, which didn't allow the possible elimination of subjects as it happened in 2 cases. For the future research we recommend focusing on higher homogeneity of subjects, at least in physical activity experience, also the cohort of people might be older, since there can be already in the pre-tests different results in muscle activity and postural stability. During EMG collection process and normalization procedures in the future research, we also recommend providing MVC tests of muscle parts in separate days of testing.

7 CONCLUSION

The aim of this master thesis was to examine the acute effect of percussive therapy on the postural stability and muscle activation in subject with and without CAI. The analysis showed high variance within individual results, thus high standard deviations across the study. Nevertheless, we found significant differences between the analyzed groups before and after the application of percussive therapy. However, not all results showed clear indications of therapy effect in terms of intragroup (pre vs. post-test within same groups). It seems, that there exist differences between CAI and non-CAI subjects, and also that PT may affect postural stability and muscle activation in both groups with different outcomes. Results indicated, that within dynamic movement performance, PT may affect HEALTHY subject positively in terms of lowering bilateral asymmetry, while negatively in CAI, by rising the difference between dominant and non-dominant lower limb muscle activation in calf area. Conversely, positive effect of percussive therapy on static postural stability in CAI subjects was found, with improvement in the group using PT in close stand tests with or without open eyes. Other observed parameters such as postural stability changes during unilateral stand or muscle activation did not show clear significant changes in patients with CAI who used PT. Thus, it seems from our results, that a significant change after PT use in people with CAI affect static and dynamic performance differently. Besides lower homogenous participants number and only one analyzed muscle part within calf area, we are aware of study limitations within unclear results and high individual differences. However, increased motor strategies required for unilateral standing and dynamic movements may affect the results, regardless of percussion therapy. Thus, more sensitive testing procedures in the calf area in larger homogenous population is recommended in the future research, while more dynamic movements could be analyzed. These results should add to the knowledge about the percussive therapy used in CAI population and its use within postural stability control pre-activation. The topics related to CAI itself are very interesting from a physiological, physiotherapeutic and strength and conditioning perspective, and there are still plenty of opportunities to explore this topic. Although the effect of percussive therapy in this regard has not provided completely clear answers, I suggest that its

use may be the subject of further research. These may include biochemical changes after PT use, use in rehabilitation processes in the early phase of acute ankle sprain, influence on the CNS and its changes observable on MRI, etc.

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Figure 22 - Difference between groups when measuring EMG (flamingo test – difference between the DOM and NON in %). Shown pairwise comparisons (HNPO/CNPO) were calculated as statistically significant ($p<0.05$).

Figure 23 - Difference between groups when measuring EMG (OE – difference between the DOM and NON in %). Shown pairwise comparisons (CYPO/CNP) were calculated as statistically significant ($p<0.05$).

Figure 24 - Difference between groups when measuring EMG (FLAMINGO - DOM STAND NON-AIR) Shown pairwise comparisons (HNPO/HYP; HNPO/CNPO; HNPO/CNP; HNPO/CYP; HNPO/HYPO) were calculated as statistically significant ($p<0.05$).

Figure 25 - Difference between groups when measuring EMG (HEEL RISE DOM). Shown pairwise comparisons (CYPO/HYPO; CYPO/HYP) were calculated as statistically significant ($p<0.05$).

Figure 26 - Difference between groups when measuring EMG (HEEL RISE DOM). Shown pairwise comparisons (CNP vs. CYPO) measured p=0,067.

Figure 27. Difference between groups when measuring EMG (HEEL RISE DOM vs. NON (%)). Shown pairwise comparisons (HYPO/CYPO; HYPO/CNPO; HYPO/HNPO) were calculated as statistically significant ($p<0.05$).

Figure 28. - Difference between groups when measuring EMG (HEEL RISE DOM vs. NON (%)). Shown pairwise comparisons (CYPO/HYP) were calculated as statistically significant ($p<0.05$).

11 APPENDIX 1

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José Martího 31, 162 52 Praha 6-Veleslavín

Žádost o vyjádření Etické komise UK FTVS

k projektu výzkumné, kvalifikační či seminární práce zahrnující lidské účastníky

Název projektu: Effect of percussive therapy on postural stability and muscles activation in people with chronic ankle instability

Forma projektu: výzkumná práce - diplomová práce

Období realizace: 11/2022 – 07/2023

Výzkum bude realizován v souladu s platnými epidemiologickými opatřeními Ministerstva zdravotnictví ČR.

Předkladatel: Bc. Lukáš Michal

Hlavní řešitel: Bc. Lukáš Michal

Spoluřešitel:

Místo výzkumu (pracoviště): UK FTVS, Laboratoř Sportovní Motoriky

Konzultant: doc. Mgr. Michal Šteffl, Ph.D.

Vedoucí práce (v případě studentské práce): PhDr. Mikuláš Hank, Ph.D.

Finanční podpora:

Popis projektu: Cílem práce je zjištění velikosti efektu masážní pistole TheraGun na úroveň posturální stability a svalové aktivity. V rámci výzkumné části bude analyzované skupině aplikována 30sekundová masáž na m. triceps surae po celé délce pomocí pistole TheraGun PRO odpovědným fyzioterapeutem. Druhá, kontrolní skupina bude přeměřena dvakrát bez masážních technik s odpovídajícím časovým posunem. Úroveň svalové aktivity bude měřena neinvazivní, povrchovou elektromyografickou metodou. Úroveň posturální stability bude měřena pomocí tlakových desek. Měření bude probíhat v Laboratoři Sportovní Motoriky na FTVS UK. Primární přínos práce spočívá v reliabilní interpretaci výsledků a testování hypotéz o míře účinnosti perkusivní terapie v oblasti dolních končetin u sportující populace dospělých probandů.

Charakteristika účastníků výzkumu: Výzkumu se zúčastní 44 probandů ve věku 25 let ± 5 let. Všichni testovaní budou mít platnou zdravotní-sportovní prohlídku, a budou aktivní sportovci, kteří ale v posledních 2 letech prodělali jednou či vícekrát luxaci, případně distorzi kotníku podle lékařské správy. Kontrolní skupina bude bez této diagnózy. Do projektu nemůžou být zapojeni probandi s paraplegií, ženy v pokročilém stádiu těhotenství, probandi, kteří v posledních 7 dnech před měřením prodělali horečnatá nebo akutně zánětlivá onemocnění. Dále nebudou moci výzkum absolvovat probandi se současnou i již vyléčenou rupturou m. gastrocnemius, m. soleus, tendo calcaneus, dále probandi, kteří mají hnisavá, plísňová onemocnění, popáleniny, opařeniny, křečové žíly či jakákoliv neuropatická onemocnění nebo i ti, kteří jsou v rekonvalescenci po nemoci či úraze.
Probandi budou osloveni skrz sociální síť instagram a na půdě FTVS UK.

Zajištění bezpečnosti: Metoda výzkumu bude neinvazivní. Veškeré masírování TheraGun masážní pistolí i samotné měření povrchovou elektromyografií a postojem na tlakových deskách bude prováděno v Laboratoři Sportovní Motoriky FTVS UK pod dohledem laboratorního personálu s minimální zkušeností 2 roky v obsluze příslušné technologie. Na sběr dat bude dohlížet PhDr. Mikuláš Hank, Ph.D., fyzioterapeut Ferdia Fallon Verbruggen, Msc, a konzultant diplomové práce doc. Mgr. Michal Šteffl, Ph.D. Masírování TheraGunem bude prováděno hlavním řešitelem. Proškolení o využívání TheraGun masážní pistole bylo provedeno Bc. Janem Kalistou z firmy REHASPORT TRADE s.r.o., oficiálním distributorem TheraGun pistolí dne 15.9.2022.
Metoda elektromyografie (EMG) studuje funkci kosterního svalstva na základě vyšetření elektrických biosignálů prostřednictvím povrchových elektrod (senzorů elektrické aktivity). Tlakové desky FootScan využívající tlakových senzorů pro měření statické i dynamické rovnováhy, respektive posturální stability. Za proškolení hlavního řešitele bude zodpovědný pracovník Laboratoře sportovní motoriky a vedoucí DP - PhDr. Mikuláš Hank, Ph.D.
Budou zajištěné standardní podmínky prostředí a příprava účastníků k provádění aktivit v rámci daného výzkumu. Bezpečnost bude zajištěna standardním způsobem. Bezpečné prostředí zajistí pracovník laboratoře a vedoucí DP - PhDr. Mikuláš Hank, Ph.D.
Rizika prováděného průzkumu nebudou vyšší než rizika běžně očekávaná u tohoto typu výzkumu.

Etické aspekty výzkumu: Výzkum nezahrnuje vulnerabilní jedince.

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Potenciální střet zájmů: Zvolené téma bude vypracováno čistě z akademických důvodů a já, jako výzkumník, spoluřešitel, konzultant, ani vedoucí práce nemáme k tématu žádné bližší vztahy ani osobní výhody. K dané terapii a metodám využitých v této práci nemáme žádné bližší vztahy, rozhodnutí výběru stálo pouze na zvědavosti ohledně spektra funkcionality nynějších trendů v poli masážních pomůcek. Jakýkoliv vztah ke konkrétní masážní pomůcce, jejich prodejcům a distributorům negujeme.
Předkladatel ani žádný členové výzkumného týmu nemá soukromý zájem na výsledku výzkumu a ani výzkum nevede k osobnímu prospěchu.

Ochrana osobních dat: Data budou shromažďována a zpracovávána v souladu s pravidly vymezenými nařízením Evropské Unie č. 2016/679 a zákonem č. 110/2019 Sb. – o zpracování osobních údajů. Budou získávány následující osobní údaje: jméno, příjmení, rok narození, váha, výška, data z výše uvedených metod, které budou bezpečně uchovány na heslem zajištěném počítači v uzamčeném prostoru, přístup k nim bude mít hlavní řešitel.
Uvědomuji si, že text je anonymizován, neobsahuje-li jakékoli informace, které jednotlivě či ve svém souhrnu mohou vést k identifikaci konkrétní osoby - budu dbát na to, aby jednotlivé osoby nebyly rozpoznatelné v textu práce. Osobní data, která by vedla k identifikaci účastníků výzkumu, budou bezprostředně do 1 dne po testování anonymizována.
Získaná data budou zpracovávána, bezpečně uchována a publikována v anonymní podobě ve výzkumné práci, případně v odborných časopisech, monografiích a prezentována na konferencích, případně budou využita při další výzkumné práci na UK FTVS.

Pořizování fotografií/videí/audio nahrávek účastníků: Během výzkumu nebudou pořizovány žádné fotografie, audionahrávky ani videozáznam.
Text informovaného souhlasu (IS): přiložen.

Povinnosti **všech účastníků výzkumu na straně řešitele** je chránit život, zdraví, důstojnost, integritu, právo na sebeurčení, soukromí a osobní data zkoumaných subjektů, a podniknout k tomu veškerá preventivní opatření.
Odpovědnost za ochranu zkoumaných subjektů leží vždy na účastnících výzkumu na straně řešitele, nikdy na zkoumaných, byť dali svůj souhlas k účasti na výzkumu. Všichni účastníci výzkumu na straně řešitele musí brát v potaz etické, právní a regulační normy a standardy výzkumu na lidských subjektech, které platí v České republice, stejně jako ty, jež platí mezinárodně.

Potvrzuji, že tento popis projektu odpovídá návrhu realizace projektu a že při jakékoli změně projektu, zejména použitých metod, zašlu Etické komisi UK FTVS revidovanou žádost.

V Praze dne: 21. 11. 2022 Podpis předkladatele:

Datum a podpis odpovědného pracovníka z místa výzkumu:

Vyjádření Etické komise UK FTVS

Složení komise: **Předsedkyně:** doc. PhDr. Irena Parry Martínková, Ph.D.
Členové: prof. MUDr. Jan Heller, CSc. Mgr. Eva Prokešová, Ph.D.
prof. PhDr. Pavel Slepička, DrSc. Mgr. Tomáš Ruda, Ph.D.
PhDr. Pavel Hráský, Ph.D. MUDr. Simona Majorová

Projekt práce byl schválen Etickou komisí UK FTVS pod jednacím číslem: 208/2022
dne: 22. 11. 2022

Etická komise UK FTVS zhodnotila předložený projekt a **neshledala rozpory** s platnými zásadami, předpisy a mezinárodní směrnicemi pro provádění výzkumu zahrnujícího lidské účastníky.

Řešitel projektu splnil podmínky nutné k získání souhlasu Etické komise UK FTVS.

UNIVERZITA KARLOVA
Fakulta tělesné výchovy a sportu
José Martího 31, 162 52, Praha 6
-- 20 --
razítko UK FTVS

podpis předsedkyně EK UK FTVS

12 APPENDIX 2

UNIVERZITA KARLOVA
FAKULTA TĚLESNÉ VÝCHOVY A SPORTU
José Martího 31, 162 52 Praha 6- Veleslavín

INFORMOVANÝ SOUHLAS k žádosti 208/2022

Vážený pane, vážená paní,

v souladu se Všeobecnou deklarací lidských práv, nařízením Evropské Unie č. 2016/679 a zákonem č. 110/2019 Sb. – o zpracování osobních údajů a dalšími obecně závaznými právními předpisy *jakož jsou zejména Helsinská deklarace, přijatá 18. Světovým zdravotnickým shromážděním v roce 1964 ve znění pozdějších změn (Fortaleza, Brazílie, 2013); Zákon o zdravotních službách a podmínkách jejich poskytování (zejména ustanovení § 28 odst. 1 zákona č. 372/2011 Sb.) a Úmluva o lidských právech a biomedicíně č. 96/2001, jsou-li aplikovatelné),* Vás žádám o souhlas s Vaší účastí ve výzkumném projektu na UK FTVS v rámci výzkumné práce s názvem „Effect of percussive therapy on postural stability and muscles activation in people with chronic ankle instability" prováděné v laboratoři sportovní motoriky UK FTVS.

Projekt bude probíhat v období: listopad 2022–červenec 2023
Výzkum bude realizován v souladu s platnými epidemiologickými opatřeními Ministerstva zdravotnictví ČR.

Cílem práce je objasnění vlivu masážní pistole TheraGun na svalovou aktivitu a posturální stabilitu. Způsob zásahu bude neinvazivní.

- V případě skupiny č. 1 (s TheraGunem) - před masáží i po ní budete změřeni na elektromyografu (EMG) a tlakových deskách FootScan (FS).
- V případě skupiny č. 2 (kontrolní skupina) - stejný princip měření, jen v mezičase mezi měřeními budete sedět bez dalšího zásahu maséra.

Měření na přístroji EMG ani FS není invazivní. Budou Vám připevněny na lýtkové svaly elektrody vázající se k EMG. Následně bude při došlapu na FS docházet k získávání dat z EMG, kde protokol obsahuje měření ve stoje na obou i jedné noze. Aplikace měření na všech přístrojích proběhne za standardních bezpečnostních podmínek proškolenými pracovníky laboratoře.
Časová náročnost projektu: výzkum proběhne jednorázově v laboratoři sportovní motoriky UK FTVS.
Časově cca 10 minut, masážní techniky budou provedeny jednou, měření dvakrát.
30sekunodvá masáž obou lýtek. Skupina č. 2 (tj. bez masáže) bude kontrolní.
Veškeré masážní procedury i samotné měření na jednotlivých přístrojích bude prováděno hlavním řešitelem a proškolenými pracovníky Laboratoře sportovní motoriky UK FTVS, na experiment bude dohlížet PhDr. Mikuláš Hank, Ph.D. a členové laboratoře sportovní motoriky.

Metoda masáže TheraGun může způsobit určité nepohodlí, velmi mírnou bolest v ojedinělých případech. Prosím informujte vždy o případné bolesti examinátora.

Budou zajištěné adekvátní podmínky prostředí a adekvátní příprava účastníků k provádění aktivit v rámci daného výzkumu. Rizika prováděného výzkumu nebudou vyšší než běžně očekávána rizika u aktivit a testování prováděných v rámci tohoto typu výzkumu. Bezpečnost bude zajištěna standardním způsobem.

Do projektu nemůžou být zapojeni lidé s paraplegií, ženy v pokročilém stádiu těhotenství, lidé, kteří v posledních 7 dnech před měřením prodělali horečnatá nebo akutně zánětlivá onemocnění. Dále nebudou moci experiment absolvovat lidé se současnou i již vyléčenou rupturou m. gastrocnemius, m. soleus, tendo calcaneus. Lidé, kteří mají hnisavá, plísňová onemocnění, popáleniny, opařeniny, křečové žíly či jakákoliv neuropatická onemocnění nebo i ti, kteří jsou v rekonvalescenci po nemoci či úraze. Přínosem tohoto výzkumného projektu pro Vás bude namasírování, participace na výzkumném projektu a seznámení se s druhou stranou sportovního prostředí.

Vaše účast v projektu je dobrovolná a nebude finančně ohodnocená.

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Ochrana osobních dat: Data budou shromažďována a zpracovávána v souladu s pravidly vymezenými nařízením Evropské Unie č. 2016/679 a zákonem č. 110/2019 Sb. – o zpracování osobních údajů. Budou získávány následující osobní údaje – jméno, příjmení, rok narození, váha, výška, data z výše uvedených metod – které budou bezpečně uchovány na heslem zajištěném počítači v uzamčeném prostoru, přístup k nim bude mít hlavní řešitel.
Uvědomuji si, že text je anonymizován, neobsahuje-li jakékoli informace, které jednotlivě či ve svém souhrnu mohou vést k identifikaci konkrétní osoby – budu dbát na to, aby jednotlivé osoby nebyly rozpoznatelné v textu práce. Osobní data, která by vedla k identifikaci účastníků výzkumu, budou bezprostředně do 1 dne po testování anonymizována.
Získaná data budou zpracovávána, bezpečně uchována a publikována v anonymní podobě ve výzkumné práci, případně v odborných časopisech, monografiích a prezentována na konferencích, případně budou využita při další výzkumné práci na UK FTVS.
Pořizování fotografií/videí/audio nahrávek účastníků: Během výzkumu nebudou pořizovány žádné fotografie, audionahrávky ani videozáznam.

S celkovými výsledky a závěry výzkumného projektu se můžete seznámit na emailové adrese: lukasmichal1998@gmail.com

V maximální možné míře zajistím, aby získaná data nebyla zneužita.

Jméno a příjmení předkladatele a hlavního řešitele projektu – Lukáš Michal

Jméno a příjmení osoby, která provedla poučení – Lukáš Michal Podpis: .....

Prohlašuji a svým níže uvedeným vlastnoručním podpisem potvrzuji, že dobrovolně souhlasím s účastí ve výše uvedeném projektu a že jsem měl(a) možnost si řádně a v dostatečném čase zvážit všechny relevantní informace o výzkumu, zeptat se na vše podstatné týkající se účasti ve výzkumu a že jsem dostal(a) jasné a srozumitelné odpovědi na své dotazy. **Potvrzuji, že mám platnou zdravotní prohlídku**. Byl(a) jsem poučen(a) o právu odmítnout účast ve výzkumném projektu nebo svůj souhlas kdykoli odvolat bez represí, a to písemně Etické komisi UK FTVS, která bude následně informovat předkladatele projektu. Dále potvrzuji, že mi byl předán jeden originál vyhotovení tohoto informovaného souhlasu.

Místo, datum .....

Jméno a příjmení účastníka ..... Podpis: .....